UNITED STATES
DEPARTMENT OF AGRICULTURE
Miscellaneous Publication No. 273

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Issued February 1938
Slightly revised April 1939

INSECT ENEMIES OF WESTERN FORESTS

Compiled by

F. P. KEEN
Senior Entomologist
Division of Forest Insect Investigations
Bureau of Entomology and Plant Quarantine

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CONTENTS

[1] For many years entomologists of the Bureau of Entomology and Plant Quarantine engaged in the study of forest-insect problems have considered compiling the great mass of records in their files so that it would be in more usable form. There has been a growing need for a manual or handbook for use by forest rangers and others entrusted with the administration of forest lands and the prevention of insect losses. Recently the tremendous impetus given to forest conservation by the establishment of the Civilian Conservation Corps camps has made insect control an actuality in many forests where previously it had been impractical. This called for the instruction and education of these men and of their leaders and has crystallized efforts toward bringing together the material in this handbook. In compiling this manual all sources of information have been drawn upon to make the presentation as comprehensive and up to date as possible. Published bulletins, records in the files, unpublished work of field men, and previously mimeographed manuals or instructions issued by the leaders of the forest-insect field laboratories of the Bureau of Entomology and Plant Quarantine in the Western States have been used as needed. It is obviously impossible to give full credit to all the workers who have contributed to the making of this publication. F. P. Keen has taken the initiative in its compilation, with the assistance of J. M. Miller, J. C. Evenden, and J. E. Patterson, and, in fact, the entire technical personnel of the Bureau's western forest-insect laboratories have contributed parts in their respective specialties. This manual is restricted to the insects of the western forests, although the general discussion and control methods are in a large measure applicable to any part of the United States. It is planned to follow this with another manual covering the eastern forests.—F. C. Craighead, in charge, Division of Forest Insect Investigations.

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INTRODUCTION

Protecting forests from destruction is the first basic requirement in the practice of forestry. Important destructive agencies include not only fire but also insect pests, fungous diseases, animals, drought, flood, and wind. While damage from insects to timber is less spectacular than that caused by either fire or wind, timber losses from any of these three agencies may be of catastrophic magnitude. Moreover, insects are constantly at work in the forest and are the cause of a steady drain on timber supplies. To allow fire or insects to run unchecked in our forests is to invite disaster and seriously to threaten the present and future timber supply.

Protection from fire has been given intensive study, and notable progress has been made in fire control. Less attention has been given to the control of timber-destroying insects, partly because practical control methods have not always been available and partly because the expense of applying them has not been warranted in view of current timber values. Moreover, practicing foresters in the West have been handicapped by lack of a convenient reference manual, and as a result have considered insect control a specialized subject with which only the entomologists were prepared to deal. With the new emphasis on forest conservation, there is, however, an increasing demand by foresters for information on insects, as this information is intimately related to many phases of forest protection and management (fig. 1).

Forest insects other than tree-killing species also present many special problems. They may be encountered in every operation, from the collection of seed through the planting, growing, and harvesting of forest trees, in the handling and protection of utilized wood products, and even in the management of grazing lands. In all of these cases some special knowledge of the insects concerned and of their habits is required in order that suitable methods of prevention or control may be effectively applied.

This field handbook has been prepared to meet this need. The discussions are limited to the insects and the problems which they raise in the management and protection of the forests of the Western States, although the general principles of control are applicable to other forest regions as well. It is hoped that the information assembled will aid timber owners and foresters in recognizing the work of important western forest insects, in applying suitable control measures, or in adjusting forest practices so as to reduce losses from this source to the lowest possible point.

KINDS OF FOREST INSECTS AND THE LOSSES THEY CAUSE

All forests are swarming with insect life. This insect population serves many functions and is as much an essential part of the complex association of living, growing, and dying organisms which we call the forest as are the trees themselves.

Of the thousands of insect species found within our forests, many are harmless or even beneficial. A great many feed on dead trees and

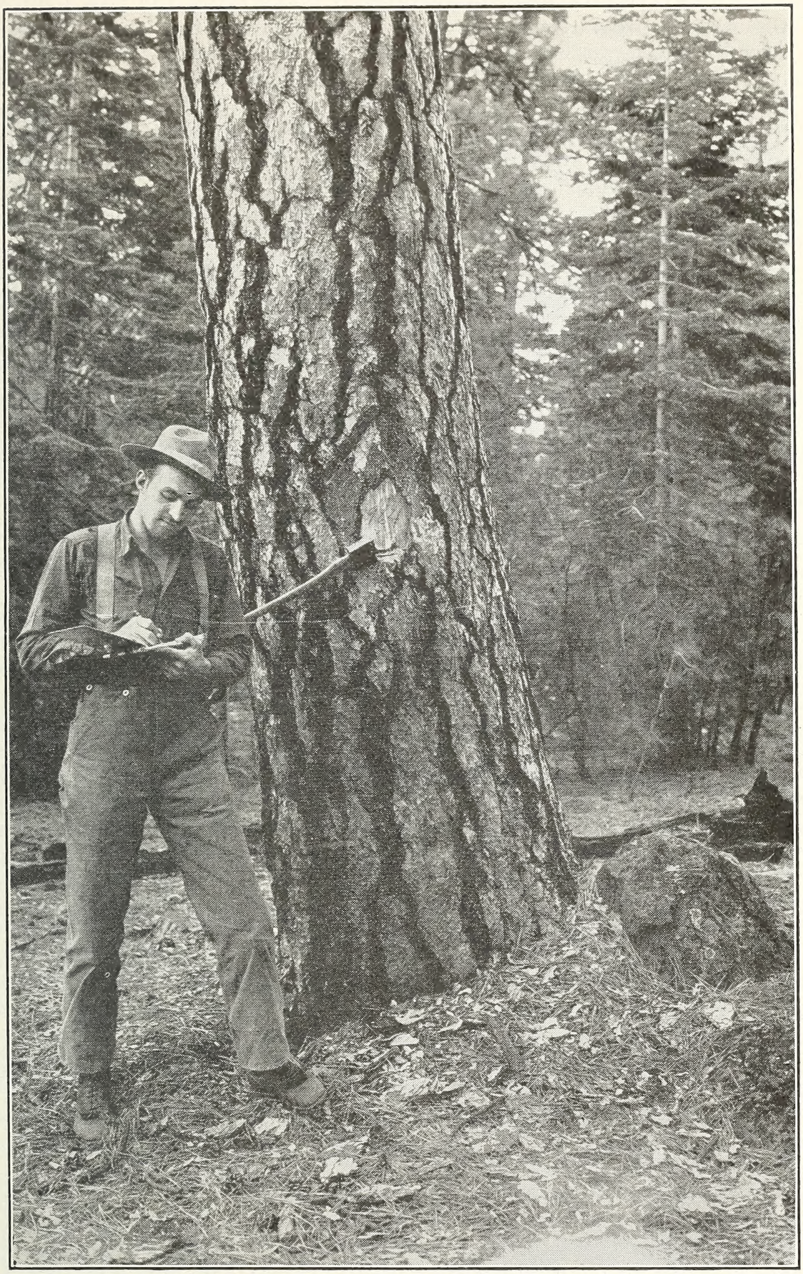

FIGURE 1.—Insect control is one of a forest ranger's many routine tasks. Marking an infested tree.

on fallen limbs and other debris upon the forest floor, and thus hasten the disintegration of dead material and make room for new growth. Many others prey upon destructive insects and hold them in check.

A certain proportion of the insect species, however, are distinctly harmful in that they attack healthy or partially weakened trees and impair their vitality or even cause their death. Of this group, bark beetles destroy more standing timber in our western forests than all other insects combined. Defoliators—insects which feed directly on the foliage of forest trees—are the next greatest destroyers of standing timber. Other insects, such as weevils, tip moths, pitch moths, and cone beetles, attack various portions of the green trees, often with serious results. In spite of the large number of insect species which prey upon the forests, comparatively few cause damage of economic importance.

The injurious species of insects may be roughly classed as primary or secondary, depending on the health of the trees which they normally attack. Thus certain species, such as the leaf-chewing insects, show a decided preference for perfectly healthy trees and are considered primary in their attack. Others, such as most bark and wood-boring insects, can inhabit only those trees previously weakened by some other agency.

From the standpoint of control it is important to know whetner an insect species is primary or secondary in its attack, as it is wasted effort to proceed against an insect, even if found apparently destructive, if its presence is conditioned by previous injury or death of the tree from other causes. It is the primary injury that must be discovered and dealt with. There are, however, a number of species that are primary under certain conditions and secondary under others.

Every species of western forest tree has its insect enemies. Western yew is probably as nearly free from insect attack as any other forest tree in the West; an occasional scale or caterpillar may be found on its foliage, and beetles on rare occasions enter its heartwood through wounds, especially if the wood is beginning to decay, but no serious enemy is known. The cedars, cypresses, redwood, and junipers have very few injurious insect enemies and none that threaten the life of mature trees. Larch also is comparatively free from insect pests. The broad-leaved trees are the favored hosts of many leaf-feeding species, but since these trees can readily replace their depleted foliage such feeding rarely results in any fatal injury. Some species, however, are much more subject to insect attack than others. Certain oaks are reported to be hosts for more than 1,000 species of insects. Pines, spruces, firs, and hemlocks suffer much, in the order named.

Injurious forest insects are constantly at work, taking toll at every stage in the development of the stand, and even after the lumber has been manufactured into its final form. Some insects feed on the roots, others on the leaves, the terminal shoots, the branches, or the phloem and bark of the main trunk. Still others feed on the sapwood, and even the heartwood. The fruits and the seeds also are subject to attack by many insect species.

In certain types of old-growth timber stands, particularly those that are overmature, steady loss through insect activity is normal.

(This loss is for the most part counterbalanced by new growth.) On the other hand, epidemic insect outbreaks occurring from time to time definitely deplete the forest capital over large areas to such an extent that long periods are required for replacement (fig. 2). Annual loss by forest insects in the Western States, including depredations on standing timber and damage to logs, sawed lumber, and finished wood products in use, is variously estimated at from $20,000,000 to $100,000,000.

A considerable portion of this loss is as unavoidable as losses from lightning or windstorms. On the other hand, much of it can be prevented through silvicultural practices, proper forest management, and direct control measures.

FIGURE 2.—Not fire but bark beetles destroyed this basin of lodgepole pine in Yosemite National Park.

DIRECT LOSSES

In the mature timber stands of the West the largest single item of insect loss results from activities of bark beetles. Surveys indicate that these pests destroy annually 1 billion to 5 billion board feet of mature timber in our western forests.

A survey made in California in 1931 indicated that losses of merchantable timber due to bark beetles in that year totaled about 1,250,000,000 board feet, which represents a loss of nearly $3,000,000 in stumpage values, aside from the regional asset represented by the manufacturing value of the lumber.

In southern and central Oregon, during the 10 years ended with 1934, the western pine beetle caused a net depletion of the ponderosa pine stands (fig. 3) amounting to 2,240,000,000 board feet. A typical section in the Klamath Indian Reservation, carrying a stand of 11,074,000 board feet in 1921, lost 3,875,000 board feet through bark-beetle attack during the 11-year period 1921–31. Growth during the same period, which, owing to drought and to defoliation by the

FIGURE 3.—Destruction of commercial ponderosa pine stands by bark beetles is a serious problem in many Western States.

pandora moth, was only 48 percent of the normal, amounted to 294,000 board feet, leaving a net loss for the 11 years of 32.3 percent of the stand.

The lodgepole pine forests of Idaho, Montana, and Wyoming, particularly those in and around Yellowstone National Park, have suffered tremendous losses in recent years. It has been conservatively estimated that during the 10 years that ended with 1932 these losses amounted to 7,250,000,000 board feet, more than 36,000,000 trees having been killed in one national forest alone. Many mature lodgepole pine forests in regions 1, 4, and 6 have been completely destroyed during the last 20 years, or are in process of destruction, by the mountain pine beetle.

During the 10-year period 1923–32 the mountain pine beetle is also estimated to have destroyed 110,000,000 board feet of valuable stands of western white pine in northern Idaho.

It must be clearly understood that these loss estimates cover the normal as well as the unusual drain on the forest. In the surveys in the ponderosa pine type of California and Oregon, for example, all trees killed by bark beetles were tabulated. Normally, on the best sites but few trees (30 to 40 M board feet per section) are thus killed each year, but on poorer sites losses of 50 to 100 M board feet per section may not be unusual. In lodgepole pine stands normal losses by bark beetles are practically negligible, so any marked losses indicate abnormal conditions.

Defoliating insects at times destroy considerable stands of mature timber. These outbreaks, however, usually occur at rather long intervals and are nearly always of short duration. In western forests some of the worst defoliators are the pine butterfly, the Douglas fir tussock moth, the spruce budworm, and the hemlock looper. In 1893–95 the pine butterfly practically wiped out the mature ponderosa pine stand on 140,000 acres of the Yakima Indian Reservation in Washington. Since then less severe outbreaks of this insect have occurred from time to time. In the 3 years 1930–32 the Douglas fir tussock moth destroyed a high percentage of the Douglas fir stands on 300,000 acres of the Colville National Forest in northeastern Washington. Along the coast of Oregon and Washington the hemlock looper appears at intervals of about 10 years and completely destroys the western hemlock and associated trees over large areas. In Pacific County, Wash., between 1930 and 1932 this insect killed approximately 200,000,000 board feet of western hemlock and other species on an area of approximately 32,000 acres. An outbreak in 1919–21 covered 500,000 acres in Tillamook and Clatsop Counties, Oreg. Defoliators in general cause either little loss or widespread destruction.

Forest plantations are particularly subject to the destructive activities of insects, chiefly because a plantation is usually made up of a large planting of a single species. Then, again, many plantations are established on soils that are not especially suitable for the tree species used; in such cases soil-infesting insects, such as white grubs, wireworms, root maggots, and cutworms, play an important part by feeding on the roots. Young trees and second-growth stands are often seriously damaged also by insects that feed on the terminals.

Bud and twig moths, tip weevils, and twig beetles not only damage and deform the terminal shoots but at times become so numerous as to kill out seedlings, saplings, and poles over large areas. Pine plantations in the Nebraska sand hills have been badly set back by tip moths. Many areas of second-growth pine near logging operations have been swept by aggressive infestations of engraver beetles.

The destruction of trees especially valuable from a recreational or aesthetic standpoint has recently come into prominence because of rapid progress in the development of forest recreation. The importance of forest cover on national parks, game preserves, and other recreational areas cannot be estimated in board-feet values. Insect depredations which mar the beauty or destroy the protective value of the forest cover on park and other recreational areas justify higher expenditures for suppression than might be reasonable on a strictly commercial stand.

Injuries to the wood of living trees are manifested in lumber as defects greatly reducing its value. Furthermore, all kinds of forest products, from the time the tree is felled and for many years after the wood is put into use, are subject to destruction by insects. Green sawlogs and storm-felled timber, green sawed lumber and seasoned lumber, rustic construction, poles, posts, cross ties, and all manner of finished products, from flooring to furniture, are attacked. Losses in finished products are particularly heavy, since they include cost of manufacture or replacement, or both. Losses of this class, it is estimated, amount to from 0.5 to 5 percent of the total value of various classes of finished products.

INDIRECT LOSSES

Besides direct damage through destruction of trees and forest products, forest-tree insects cause important indirect losses in the way of reduction in forest growth and alteration of the stand from valuable to inferior species.

In some forest types insects often are one of the chief limiting factors in successful management. They frequently upset well-organized plans aimed at the continuous production of forest crops. In the western white pine and lodgepole pine forests of the northern Rocky Mountain region bark beetles so affect the proportion of species as to convert many stands to entirely different composition. In Modoc County, Calif., a bark-beetle epidemic in a mixed second-growth stand of ponderosa pine and white fir killed out all the pine and converted the stand into pure fir.

Much less frequently the effect of insect activity on stand composition is beneficial. In the Yosemite and Crater Lake National Parks, for instance, lodgepole pine stands completely destroyed by bark beetles have been succeeded by stands of the hemlock-fir type, which, for park purposes at least, is far superior to the lodgepole pine type.

Certain defoliators, even though they do not kill the timber, may cause a cessation or reduction of growth which may increase the rotation period of the stand by from 5 to 10 or more years, or they may so weaken the trees as to make them easy prey for tree-killing bark beetles. Such defoliation may be local and confined to a single tree species, or may spread over an enormous area and involve sev-

eral species. For instance, an outbreak of the pandora moth in the ponderosa pine stands of southern Oregon, between 1918 and 1925, covered approximately 400,000 acres. Growth measurements on plots on this area showed that over a period of 11 years the normal forest increment was reduced by an average of 32 percent, or approximately 100,000,000 board feet. The weakening of these trees was followed by heavy bark-beetle killing, as much as 30 percent of some stands having been killed by the beetles.

The spruce budworm, which is so destructive in the Northeast and in Canada, is present also in the Douglas fir and balsam fir forests of the northern Rocky Mountains and the Pacific Northwest. Outbreaks of this insect, besides resulting in destruction of extensive stands of Douglas fir in the Rocky Mountain region, have left many trees in a weakened condition that renders them susceptible to bark-beetle attack. Many other defoliators, by partially reducing the leaf surface of trees, adversely affect their growth; and in most cases the forester has little opportunity to prevent this damage.

Another indirect result of bark-beetle and defoliator damage is increase in forest-fire hazard. The old snags of insect-killed trees scattered throughout mature forests, averaging on some ponderosa pine areas as many as 10 per acre, stand for many years and greatly increase the cost, difficulty, and danger in fire control. The felling of snags is now required in many sales of national-forest timber, and many private operators have adopted this precautionary measure. The cost of controlling forest fires that have spread from burning snags within fire lines would alone justify large expenditures for insect control.

After the defoliation of large forest areas, the debris beneath the stripped trees dries out quickly and becomes highly inflammable. A flash of lightning, or a carelessly handled match or cigarette sets off the mass, causing a widespread conflagration almost impossible to control. Heavy defoliations in Douglas fir and hemlock stands and epidemics of the mountain pine beetle in lodgepole pine have put the forest in such a condition that, more often than not, forest fires have followed. The increased fire hazard is an added reason why forest-insect outbreaks should be controlled wherever possible.

RELATION OF INSECTS TO FOREST MANAGEMENT

Since the practice of forestry is concerned with the growth, protection, and perpetuation of timber resources, it must take into consideration any agency having so important a bearing on the growth and development of forests as insects. As has already been pointed out, insects cause enormous losses in mature stands of timber which are being held in reserve for future needs; they affect the rate of growth of developing stands and lower the yields; frequently they so change the composition of a forest that a complete reshaping of the plan of management is necessary; they take a varying toll from crude and finished forest products; and they create serious fire hazards. For these reasons insect problems enter into nearly every phase of forest management and protection.

Under virgin-forest conditions no checks were placed on the activities of destructive agencies other than those imposed by Nature her-

self. Fires as well as insects and disease outbreaks developed, spread destruction, and ran their course. The whole process was very wasteful but seldom resulted in the permanent destruction of the forests over any large areas. Natural checks were imposed and the processes of regeneration were brought into play.

With the development of the country and a corresponding increase in values came the necessity for better protection and management. The first step in stopping Nature's wasteful processes was the control of forest fires. Later, with more intensive forest management and the development of control methods, attention was turned to the prevention of losses from forest insects and disease. As time goes on and forest values increase, more and more attention will be given to preventing or controlling forest-insect damage, and a greater refinement in methods will become economically justifiable.

In a managed forest the first objective of forest-insect control is to so regulate conditions as to maintain a natural balance between the insect population that is destructive and the beneficial predacious forms, as well as between the insects and their food supply, so as to prevent the development of destructive insect outbreaks. This objective will be attained more fully in the future through silvicultural practices applied to growing stands whereby unfavorable conditions for the development of insects are maintained and a greater resistance of the stand to insect attacks is developed. This may involve such measures as prompt disposal of slash and correction of other insect-breeding conditions, the regulation of stand density and composition, the regulation of environmental factors through drainage or other methods, and the selection of insect-resistant varieties and species of trees.

When preventive methods fail to avert insect outbreaks, direct control measures must be considered. The total elimination of a forest insect is quite impractical, but fortunately this need not be attempted. Instead, the objective of direct control is the restoration of the natural balance in which the destructive insects are not greatly out of proportion to their natural enemies. In such proportions the destructive species are relatively harmless, and the damage they do is insignificant.

In view of present forest values it is hardly practical to attempt to control all insect outbreaks. Much of the insect damage to forest trees of low value will have to be allowed to run its course, for if a policy of combating all threatening insect outbreaks were adopted the cost would be enormous and in many cases would exceed the damage probable if Nature were allowed to control the epidemic in her own way. The older forests, as they stand today, are ripe and an easy prey to bark-beetle attack, and if we are not prepared to utilize such timber and are willing to wait for Nature to replace any losses by the slow process of growing a new crop of trees, no further consideration need be given to control. On the other hand, in the many cases in which timber is in demand and satisfactory control measures are available, failure to take the necessary protective measures should be viewed in the same light as failure to control forest fires.

DETERMINING CAUSES OF FOREST-TREE DAMAGE

Many agencies may cause injury or death to forest trees, so before observed damage is charged to insects, other possible causes should be investigated. Often several agencies, such as fire, insects, fungi, and physiological injuries, are so closely associated or interrelated that it is difficult to determine the primary cause of the damage.

Injury by fire is usually easy to identify. Destruction of the ground cover, scorching of the bark, and reddening of the needles constitute ample evidence of fire damage. Usually bark beetles, either primary or secondary species, attack fire-weakened trees and complete their destruction. In some areas fire scars serve as important entrance points for fungi. Witches' brooms and damage by mistletoe are frequently conspicuous in either killing small trees or so distorting them that they can never grow into timber trees. Injuries by fungi, bacteria, and higher parasitic plants are not so easily determined by the layman, and can rarely be identified without the assistance of a trained forest pathologist. The discussion of diseases, decay, and wood rots caused by these various organisms is not within the field covered by this publication.

Mechanical and physiological injuries are frequently the primary cause of sickliness, weakness, or death of forest trees. The insects that invade the wood after such injuries have occurred are usually only secondary enemies, and cannot be charged with primary responsibility under such circumstances.

In some years a combination of weather conditions causes what is known as "winter injury", "red belt", or "parch blight"; that is, all trees of certain species on exposed hillsides within definite altitudinal limits turn a bright wine-red color. The injury is thought to be due to excessive transpiration during warm periods in winter when the ground, roots, and tree trunks are frozen and water cannot rise to supply the deficiency in the leaves. Twigs are sometimes killed, but the trees usually recover unless subsequently attacked by bark beetles or fungi.

Sometimes the tender bark on the south and southwest sides of trees and the tops of branches is killed by the sun's heat. This is referred to as "bark scorch" or "sun scald." The bark breaks away from the wood and sloughs off. Such damage is rare under forest conditions but occurs more frequently in young trees grown in open plantations.

Excessive quantities of dust in the air, as along dirt roads, causes a clogging of the stomata or breathing pores of leaves and results in partial suffocation of trees. In the Western States such injury is frequently followed by an attack of scale insects, which add to the injury and in some cases have caused the death of many young trees.

Smelter smoke, and chemicals or oils deposited on the ground in some instances cause injury to trees which leads to attack by many species of insects.

Mechanical injury to trees may result from a number of causes, such as logging operations, lightning, road building, and packing of soil or exposure of roots (as in camp grounds), or from the work of animals such as bear, beaver, and porcupines and that of sap-sucking

birds. Such injury is usually inconsequential in its effect upon a forest as a whole, and trees show remarkable powers of recovery from limited mechanical injury unless insects or fungi enter to complicate the situation.

In most cases of damage by insects the source of injury is readily apparent from the very start, but even in such cases it is well to make certain whether other conditions are partly responsible before taking steps to control the insect pests. If insects are not the primary cause of injury, little benefit can be expected from the effort to control them.

A forest officer should become familiar with the appearance and characteristics of those insects capable of killing or injuring trees and destroying wood products on the area under his care. The insects he really needs to know are comparatively few, but ability to recognize the injurious forms comes only after considerable study, not only of the insect stages but of their typical work, whether it be markings on the bark and wood, tunneling of needles, or deforming of terminals. In the following discussions special emphasis is placed upon the habits and typical work of the most injurious forms; for it is through these that the forester first becomes acquainted with the destructive species, and only after considerable experience does he learn to recognize insect adults and larvae dissociated from their work and from typical host trees.

Adult insects can be distinguished from other small invertebrate animals by the fact that they have jointed bodies of three parts (head, thorax, and abdomen), breathe through tracheae, and have one pair of antennae and three pairs of legs.

The larval form is the one most frequently encountered by the forester; but unfortunately it is difficult to distinguish insects when in this form by any simple characters. Usually, however, for the forester's purpose it is sufficient to be able to recognize the larvae as those of insects of a certain group. The forester easily acquires the ability to recognize some of the more common forms through becoming familar with their work.

The insects most important from a forestry standpoint are included in seven main groups or orders under the large class Hexapoda or Insecta. These common groups (fig. 4) include the beetles (Coleoptera), butterflies and moths (Lepidoptera), wasps (Hymenoptera), flies (Diptera), scales and aphids (Homoptera), bugs (Hemiptera), and termites (Isoptera). There are a number of other orders of insects, but these are less frequently encountered. Some small animals closely related to insects, and frequently confused with them, are of importance in forestry. The mites, belonging to the class Arachnida, are sometimes injurious to trees. The spiders, belonging to the same class, are predacious and usually beneficial. The millipedes and centipedes, belonging to the classes Chilopoda and Diplopoda, are occasionally of importance in the forest.

Most insects pass through either three or four stages of development. The beetles, wasps, flies, butterflies, and moths pass through four such stages, and so are said to undergo "complete metamorphosis." The adult female lays eggs, from which the second stage, the larvae, develop. The larvae usually are soft bodied and wormlike. The larvae of beetles are called grubs; those of moths and butterflies are

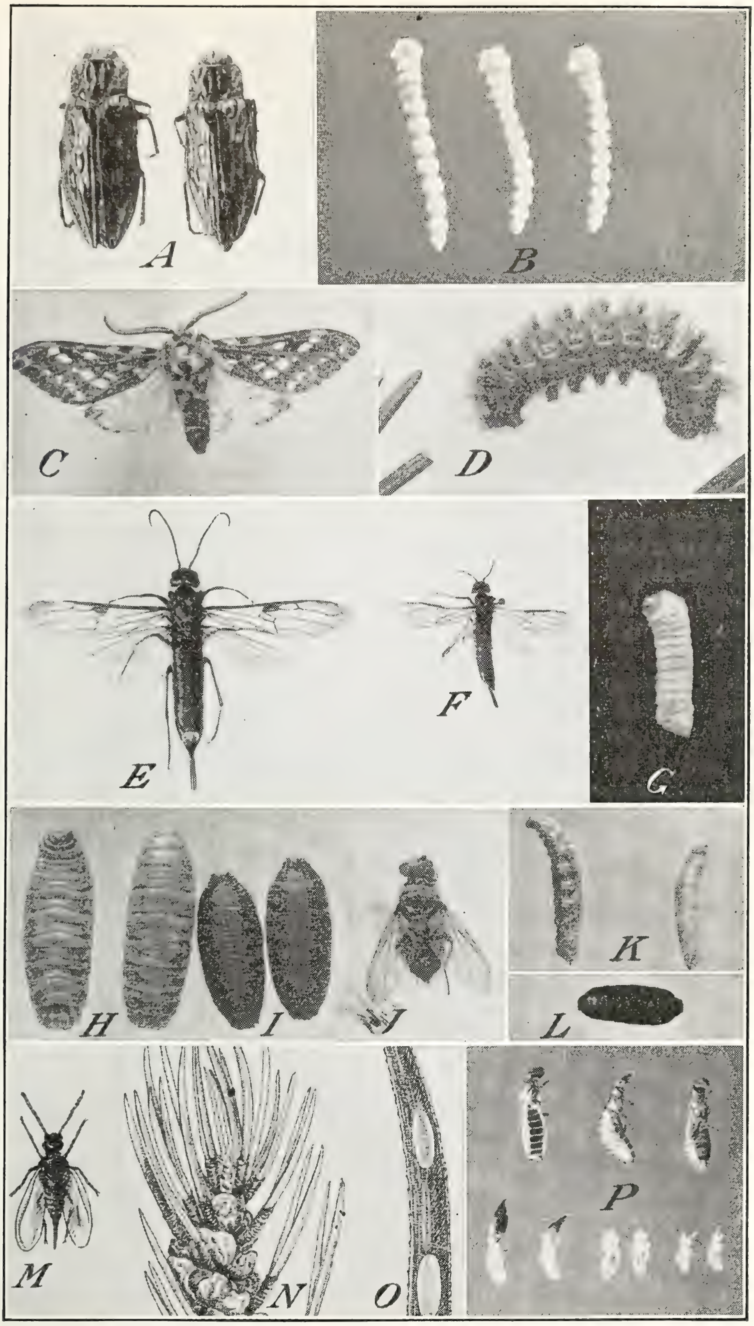

FIGURE 4.—Examples of six groups or orders to which most forest insects belong. Flat-headed beetle (Coleoptera): *A*, adults; *B*, larvae. A moth (Lepidoptera); *C*, adult; *D*, caterpillar. Wood wasp (Hymenoptera): *E*, adult female; *F*, adult male; *G*, grub. Flies (Diptera): *H* and *K*, maggots; *I* and *L*, puparia; *J*, adult fly. Scale insects (Homoptera) (drawings by Edmonston): *M*, adult male; *N* and *O*, scales on pine foliage. *P*, termites (Isoptera). All natural size; except *H*. *I*, *J*, *K*, *L*, ×2; *M*, *O*, greatly enlarged.

called caterpillars; those of flies with two clear wings are called maggots; and those of wasplike flies with four clear wings are called grubs, slugs, or false caterpillars. The larvae feed and grow, the final size which they attain being influenced to some extent by the abundance of food and moisture. As they increase in size they molt or shed their skins several times. The larvae transform to the pupal or resting stage, and the pupae in turn change to the fourth stage, the adult insects. Growth takes place only in the larval stage. Although some adult insects do some feeding, none of them increase in size. Their chief function in life is to mate and produce eggs, and thus initiate another life cycle.

Scale insects, aphids, bugs, and termites undergo what is called an "incomplete metamorphosis"; that is, they have only three forms—the egg, the nymph, and the adult. Growth takes place during the nymphal stage, in which the insect has very much the form and appearance of the adult but lacks fully developed wings.

Certain insects, such as the termites, aphids, and ants, have several specialized adult forms. Thus, in addition to the usual stages, there may be workers, soldiers, and secondary sexual forms. Certain scale insects and aphids give birth to living young without producing eggs. Others are able to reproduce by means of eggs laid by virgin females, which develop without being fertilized. In some cases, as among the gall midges, larvae are able to give birth to similar larvae without passing through other stages. These are all exceptions to the general rule.

Insect damage to trees may be caused in any one of several ways. Adults of some species cause injuries by feeding on the leaves, twigs, or tender cambium, or by slitting bark or leaves in order to deposit eggs. Adult bark beetles do considerable damage in constructing egg tunnels under the bark. Most commonly, however, the damage is done by the larvae or nymphs in their feeding on various parts of the tree. No damage is ever done by the insects while in the egg or pupal stages.

The principal methods of feeding by which insects injure trees are chewing, sucking, and gall forming. The great majority of forest insects belong to the chewing group, and in the larval or the adult stage, or both, these chew and ingest plant material. This group includes the leaf eaters, the cambium miners, and the wood borers. Aphids, scale insects, and bugs feed by sucking plant juices by means of slender mouth parts which they insert into the tender portions of the tree. A group of specialized insects irritate portions of the tree and thus cause it to form a swelling or gall which encloses them. The method of feeding has an important bearing on the methods of control.

The important forest insects might be classified, for the purpose of discussion, according to their natural relationships, according to the species of trees attacked, according to the parts of the tree affected, or according to the stage of the life of a forest tree upon which they inflict their greatest injury. For the purposes of this publication, it seemed that the last-mentioned arrangement would be the most helpful for the forest field man. In this publication, therefore, the western forest trees will be followed through their life cycle, from seed to final finished product, and at each step the insects that are of greatest importance in injuring them will be discussed.

INSECTS AFFECTING SEED PRODUCTION

The natural reproduction of forests, the artificial reforestation of denuded areas, and the future supply of timber depend to a considerable extent upon the production of a prolific supply of sound, uninjured seed. In most instances insect damage to tree seeds is not sufficiently severe to be of any great importance; in some seasons, however, insects destroy practically all the seed of certain tree species in certain localities.

Destruction of seeds may be caused by insects that attack the buds, flowers, or immature cones, as well as by those that attack the seeds themselves. Damage at these early stages causes wilting, blighting, or premature dropping of the parts affected. The fruit or cones developing after insect attack may be deformed or "wormy", riddled by the borings of various grubs, caterpillars, or maggots. In many cases the cones show no damage, but the seeds are infested with the small white larvae of seed chalcids. Even the old, hard, dry cones of certain pines are often mined by wood borers. The insects that affect seed production in these various ways belong to a number of different orders and families, of which some work only on cones or seeds while others work also in the bark or cambium of succulent growing shoots, stems, and twigs, or even in dry wood.

Knowledge of the presence of seed-infesting insects will often prevent the disappointment and loss attendant on the collecting, handling, and sowing of insect-damaged seeds (*58*).[2]

KEY TO DIAGNOSIS OF INSECT INJURY TO CONES AND SEEDS

A. Injuries to cones and coniferous seeds.
- 1. Cones wither and die before they are half grown.
  - *a.* Interior mined by small, white, curled larvae or by small dark-brown beetles; pine cones only, cone beetles, page 16.
  - *b.* Cones deformed and interior mined by active caterpillars; exterior with exudation of pitch or webbed borings ---------- cone moths, page 16.
- 2. Cones reach full growth but are riddled with insect borings.
  - *a.* Borings made by active caterpillars which leave pitchy masses of boring and excrement within the cone and similar exudations at the point of entrance, or larval mines in axis and mature seeds, without resinous exudations ------- cone moths, page 16.
  - *b.* Soft cones riddled by small white maggots which leave fine excrement in tunnels, but free from masses of pitch ---------- cone maggots, page 20.
  - *c.* Hard, dry cones of pine mined by slender, white, round-headed or flat-headed larvae, cone borers, page 21.

B. Injuries to coniferous seeds, with or without injury to cone.
- 1. Seeds show no external injury, but interior is hollowed out by small, white, curled, legless grubs ----- seed chalcids, page 21.
- 2. Seeds swollen and galled, containing small pink maggots, seed midges, page 20.

C. Injuries to nuts or seeds of broad-leaved trees.
- 1. Acorn showing no injury externally but mined by small, white, curled grub ---------- acorn weevils, page 22.
- 2. Interior of acorn mined by active caterpiller which discharges webbed frass through exit hole ---------- acorn moth, page 23.

[2] Italic numbers in parentheses refer to Literature Cited, p. 197.

CONE BEETLES

Pine cones which dry and wither before they are half grown (fig. 5), and either drop to the ground or are retained as blighted immature specimens, usually have been killed by the cone beetles, *Conophthorus* spp. (*59*).

The adults are small, dark, shining cylindrical beetles, from one-sixteenth to five thirty-seconds of an inch in length. They bore into the base or supporting stem of the immature pine cones in the spring soon after the beginning of the second year's growth. A small tunnel is projected through the axis of the cone, and in this the female beetle deposits her eggs. From these hatch small, white, curled, legless grubs which feed upon the scales, seeds, and tissues of the withering cone. Development to the adult stage is completed during the summer within the dead cone, where the beetles usually remain over the winter. The damage to the cone crops of ponderosa pine, western white pine, and sugar pine is often very severe. In some years from 25 to 75 percent of the cones of sugar pine have been killed over large areas. In other pines the damage is less conspicuous. No method of control seems feasible under forest conditions.

A number of species found in western pines have been described by Hopkins and named for their principal host trees. The following list gives the species of *Conophthorus* that may be found in western forests:

Species of Conophthorus	Hosts and distribution
C. ponderosae Hopk	Ponderosa pine, lodgepole pine, and Jeffrey pine. Pacific States.
C. scopulorum Hopk	Ponderosa pine. Rocky Mountain region.
C. lambertianae Hopk	Sugar pine and western white pine.
C. monticolae Hopk	Western white pine and ponderosa pine.
C. radiatae Hopk	Monterey pine.
C. contortae Hopk	Lodgepole pine.
C. monophyllae Hopk	Singleleaf piñon pine.
C. edulis Hopk	Piñon pine. Colorado, Arizona, and New Mexico.
C. apachecae Hopk	Apache pine. Arizona.
C. flexilis Hopk	Limber pine.

CONE MOTHS

The caterpillars of certain species of moths feed on the bracts, scales, and seeds of tender growing cones. Such feeding dwarfs or deforms the cones and sometimes causes their death, but more frequently destroys a large percentage of the seeds without killing the cones. The work of certain species is characterized by larval tunnels within the cones and an opening at the surface through which resin mixed with larval castings exudes. Other caterpillars attack the cones and mine through the axis and into the seeds without causing resinous masses or deformity of the cones.

The adults are mostly small inconspicuous moths which are seldom noticed. They usually fly early in the spring and deposit their eggs on the scales of young cones. The eggs hatch in a few days, and the young larvae bore into the cones, where they feed until fall. When the caterpillars reach full growth they form silken cocoons on the surface of the cones, among the cone scales, or in the pith, in which

they overwinter. Most moths have one generation annually, and the adults emerge the following spring, but a few may retard their emergence and appear the second or third season. Thus in the event

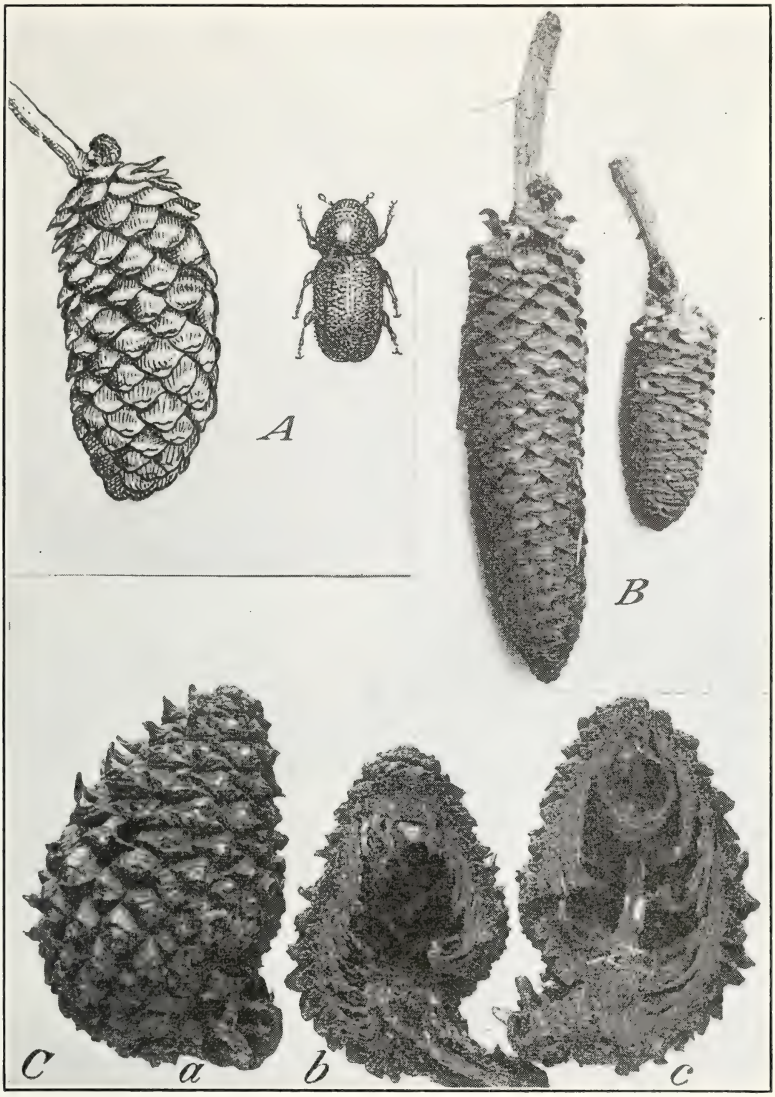

Figure 5.—Cone beetle damage: *A*, Sugar pine cone and cone beetle, the latter × 7 (drawings by Edmonston). *B*, Pitch tubes on the stem, indicating cone beetle attack. *C*, Knobcone pine cones riddled by cone beetles: *a*, Cone showing pitch tube at point of attack near stem and exit hole near center; *c*, cone showing larval excavations and adult beetle.

that one or two cone crops fail, the species is still able to survive. No methods have been devised for the control of these insects, nor would control be economically justifiable under present forest conditions.

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PINE CONE MOTHS

Pine cones are attacked early in the spring of their second year of growth by several species of cone moths. The caterpillars of one group are dirty white in color and about one-half inch in length when full grown. They burrow through the central axis of the cones and enter the seeds through the point of attachment. They are especially destructive to the seeds of ponderosa pine (fig. 6) and Jeffrey pine. Pupation takes place in the pith. The moths are small, one-half inch in length, and gray to black in color. The species included in this group are the following:

Species	Hosts and distribution
Laspeyresia piperana Kearf	Ponderosa pine and Jeffrey Pine. California, Oregon, Washington, Idaho, and Montana.
Laspeyresia miscitata Hein	Ponderosa pine and Jeffrey pine. California, Oregon, Idaho, and Nevada.
Hedulia injectiva Hein	Jeffrey pine and ponderosa pine. California, Oregon, and Nevada.

FIGURE 6.—*a*, Adult of the pine cone moth (*Laspeyresia piperana*) × 2; *b*, caterpillars feeding through ponderosa pine cone, and pupa in the pith. (Drawing by Edmonston.)

Those which are most frequently involved in this type of injury belong to the genus *Laspeyresia*.

Other cone moths which attack pine cones bore tunnels through scales and seeds. The seeds and a large portion of the interior of the cone are destroyed. Sometimes the attack distorts and deforms the cone or kills it before it reaches maturity. Most of the species of this group also feed on the succulent new growth of pines. Their work is characterized by a resinous exudation of pitch and larvel castings mixed with webbing. The following species belong in this group:

Species	Hosts
Dioryctria xanthoenobares Dyar	Ponderosa pine, knobcone pine, and other pines.
Dioryctria abietella D. and S	Pines, Douglas fir, balsam fir, and spruce.
Eucosma bobana Kearf	Ponderosa pine, Jeffrey pine, and knobcone pine.
Eucosma rescissoriana Hein	Lodgepole pine.

FIR CONE MOTHS

Cones of white fir, red fir, and other balsam firs, and of Douglas fir, are most seriously injured by the attack of small moths of the genus *Barbara* (formerly *Evetria*). The yellowish-white caterpillars mine through scales and seeds, making a tortuous resinous tunnel and an opening at the surface through which resin and larval castings exude. The pupae overwinter near the axis of the cone in a papery, resin-coated cocoon among the resin-matted scales. The adults, which are gray moths about one-half inch in length and with speckled forewings, emerge the following spring and lay their eggs on the young budding tender cones. The several species and varieties listed below cause this type of damage:

Species	Hosts and distribution
Barbara colfaxiana Kearf	Douglas fir. California, Oregon, Washington, and British Columbia.
Barbara colfaxiana var. *taxifoliella* Busck	Douglas fir. Idaho and Montana.
Barbara colfaxiana var. *coloradensis* Hein	Douglas fir and white fir. Colorado.
Barbara colfaxiana var. *siskiyouana* Kearf	White fir and red fir. California and Oregon.
Barbara ulteriorana Hein	Douglas fir. Oregon.

Similar damage to fir cones is frequently caused by the caterpillars of the cone pyralid, and the fir cone geometrid.

The cone pyralid, *Dioryctria abietella* D. and S. (fig. 7), in the full grown larval stage is a large, active, irridescent, greenish-red caterpillar three-fourths of an inch in length, which bores through scales and seeds of Douglas fir, balsam fir, pine, and spruce cones, leaving a round clean-cut hole. In contrast to the work of *Barbara* its webbed castings on the surface of an infested cone are free from pitch. The adults are gray moths mottled with black and have a wing expanse of about 1 inch.

FIGURE 7.—A fir cone moth (*Dioryctria abietella*), slightly enlarged, and typical damage to Douglas fir cones. (Drawings by Edmonston.)

The fir cone geometrid *Eucymatoge spermaphaga* Dyar in the adult stage is a gray moth with black and red-brown markings and a wing expanse of about 1 inch. The caterpillars, which are somewhat similar to the above, are of the measuring worm type. They bore through seeds and cone scales of Douglas fir, the balsam firs, mountain hemlock and probably other conifers.

Another group of small moths, belonging to the genus *Laspeyresia*, are destructive to fir, spruce, and other cones. The larvae are less than one-half inch in length when full grown, pink or white in color, with a few bristles. The moths are small and dull colored. They are of the following species:

Species	Hosts
Laspeyresia bracteatana Fern	White fir, red fir, and other firs.
Laspeyresia youngana Kearf	Spruce.
Laspeyresia cupressana Kearf	Monterey cypress.

Cones of incense cedar in Oregon are sometimes injured by the slugs of a sawfly (*Augomonoctenus libocedri* Rohw.) which does work similar to that of cone-feeding caterpillars. The adults are one-fourth to three-eighths of an inch long, shining blue-black, with the first five segments of the abdomen brick red.

FIGURE 8.—Cone maggots (*Lonchaea viridana*) are commonly destructive to seeds of white fir. × 2.

CONE MAGGOTS

The insects encountered in seed collecting probably more often than any other group are small, white or pink, legless maggots which emerge from the cones in vast numbers as these are spread out to dry. These are the larvae (fig. 8) of tiny gnats, midges, or flies. A few cause considerable injury to cones and seeds, whereas others do no appreciable damage.

Cone and seed midges (Cecidomyiidae) are found in cones as small pink maggots, the larvae of small gall gnats or midges. The adults are small and very similar in appearance to mosquitoes. They lay their eggs on the young, green cones, and the maggots work within and cause little masses of resin to form among the cone scales or cause hard resinous galls to form on the scales or in the seeds. The damage from these insects is usually insignificant. Of the many western species, only one, *Janetiella siskiyou* Felt, from the seeds of Port Orford cedar, has been named.

The white fir cone maggot (*Lonchaea viridana* Meig.) is the common white maggot found so abundantly in white fir and other balsam fir cones (fig. 8). These maggots mine through scales and seeds, often causing great damage. The larvae leave the cones as soon as they fall and form small puparia in the ground. Here they overwinter, and in the spring some of them emerge as small, black, shining flies. The great majority of the brood go through a 2-year life cycle, emerging the second spring after pupation.

CONE BORERS

The hard, dry cones of certain pines are frequently attacked by the larvae of flatheaded and roundheaded borers which riddle the interior and destroy the seeds.

The roundheaded cone borer (*Paratimia conicola* Fisher) has the habit of boring tunnels through the hard pitch and scales of knobcone pine cones. It works also in the dry limbs of the species. The adults are a rusty reddish brown, and one-half inch in length.

The flatheaded cone borer (*Chrysophana placida* Lec.) has been found boring through the hard, dry cones of knobcone and ponderosa pine. It also bores in the dead limbs, branches, trunks, and stumps of practically all western pines and firs. In the adult stage it is a small green or greenish-red beetle, about one-half inch in length.

SEED CHALCIDS

Seeds of many conifers are attacked by small wasps of the genus *Megastigmus* (*71*), which drill through the young green cones with their long ovipositors and lay their eggs within the immature seeds (fig. 9). The small, white, legless larvae feed on and destroy the tissue within the seeds. The normal outer shell is formed later and shows no evidence on the surface that the seed is infested. The feeding habits of these insects are similar to those of the gall makers. In the following spring the larvae reach maturity and emerge as small yellow or nearly black wasps. Each adult leaves a smooth round emergence hole in the seed coat. Some hold over and emerge the second or even the third year. The damage by these seed-infesting insects is an important factor in seed collecting, and often a high percentage of cleaned commercial seed will be found to have been ruined by these insects.

There appears to be no practical means of preventing this damage; but to avoid the introduction of this insect into other countries, infested seeds should be fumigated in a tight container with carbon disulphide. As this fumigant has a deleterious effect upon the germination of the seed if used in excessive dosages, not more than 1 ounce of fumigant should be used to 100 pounds of seed, and the fumigant should be completely removed by thoroughly aerating the seeds after they have been in the container for 48 hours. Carbon disulphide vapor mixed with air is explosive, and fire should be guarded against. Calcium cyanide may prove to be a more satisfactory fumigant, but which form of it should be used and how it affects the germination of seeds has not yet been fully determined. Since the gas evolved from calcium cyanide is a deadly poison this material should be used with caution, preferably by persons who have had experience with it.

The different species of this genus and the hosts from the seed of which they have been reared are as follows:

Species	Hosts
Megastigmus albifrons Walk.	Ponderosa pine.
Megastigmus lasiocarpae Crosby	Alpine fir.
Megastigmus picea Rohw.	Blue spruce, Engelmann spruce, and Sitka spruce.
Megastigmus pinus Parfitt	Silver fir, lowland white fir, white fir, Shasta fir, and bristlecone fir.
Megastigmus tsugae Crosby	Mountain hemlock.
Megastigmus spermotrophus Wachtl (*60*)	Silver fir, bristlecone fir, grand fir, red fir, white fir, Douglas fir, and other conifers.

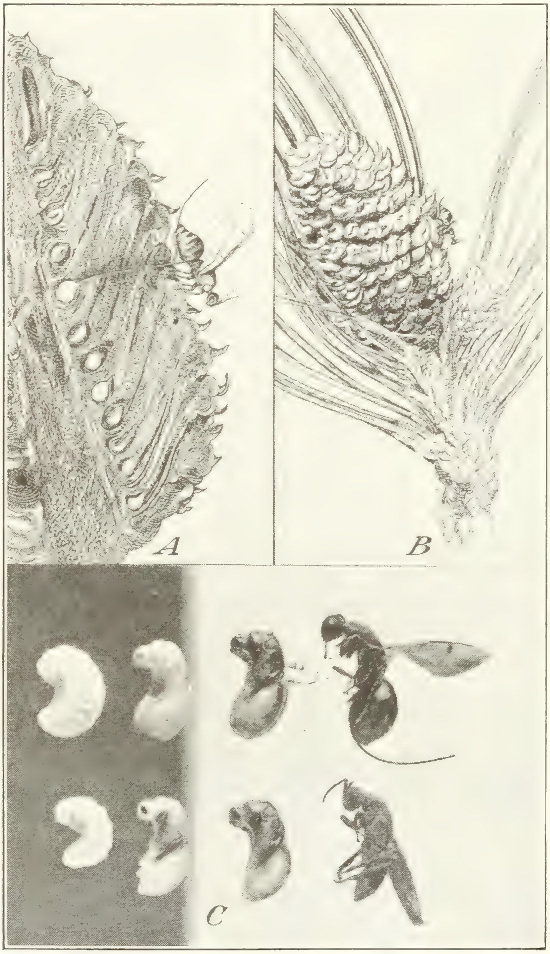

FIGURE 9.—*A* and *B*, Adults of the ponderosa pine seed chalcid (*Megastigmus albifrons*) laying eggs through small green cones into seeds (drawings by Edmonston). Enlarged. *C*, Larvae, pupae, and adults of same species of *Megastigmus*, × 3. Female above, male below.

NUT AND ACORN WEEVILS

Nuts and acorns of various western hardwoods are frequently infested by the curled white grubs of the nut and acorn weevils, belonging to the genus *Balaninus*. The adults are medium-sized, yellow, brown, or nearly black weevils with robust bodies, long legs, and prominent, slender, curved or nearly straight beaks. The adults appear in the summer. With their beaks they gnaw holes in the shells of new acorns or nuts and in these they place their eggs. The larvae feed on the meat and destroy the seed. The winter is passed in the larval stage, either within the acorn or in the ground. Pupation occurs the next spring, and the adults emerge in the summer. Several

species of *Balaninus* are found in the Western States. These are listed below:

Species	Hosts and distribution
Balaninus uniformis Lec.	Oak acorns. New Mexico, Arizona, Utah, California, Oregon, and Washington.
Balaninus caryae Horn	Hickory, pecans. Eastern States and westward into Colorado.
Balaninus rectus Say	Chestnuts, acorns. Eastern States and westward into Arizona.
Balaninus nasicus Say	Oak acorns. Eastern States and westward into New Mexico and Arizona.
Balaninus q-griseae Chittn.	Griseous oak acorns. Arizona.

ACORN MOTH

Small white or pinkish caterpillars, about three-fourths of an inch in length when full grown, the immature stage of the acorn moth (*Melissopus latiferranus* Wls.), may at times be found boring through acorns and throwing out larval castings, which are held together by a web, at the entrance hole. They also infest the seeds of Catalina cherry in southern California and may likewise be found in the large green cynipid galls formed on various oaks. There is only one brood a year, and the larvae hibernate in cocoons within the ground.

INSECTS INJURIOUS TO SEEDLINGS IN NURSERY OR FOREST

In nurseries and plantations, and even in natural forests, young seedlings are the easy prey of a great variety of insect enemies. In seedbeds the nurseryman must guard against insects as well as against damping off, rodents, heat injury, and unfavorable soil conditions. In transplant beds insect damage may be more severe than in the seedbeds. In some cases white grubs alone have destroyed 90 percent of seedlings planted in badly infested soils. In western nurseries the strawberry root weevils have occasionally taken a heavy toll in the transplant beds. Cutworms, grasshoppers, leafhoppers, and other insect pests become abundant at intervals. After planting in the forest, nursery stock is subject to damage by a great many insect enemies before it becomes well established and able to resist attack. So far, western forest nurseries have been more fortunate than those in the East in escaping troublesome insect pests.

It is at these early stages in the tree's life cycle that root-feeding insects do their greatest damage. After the trees have become fully established in the field and have developed a large root system there is less danger that soil-infesting insects will injure them seriously. Most of the soil-inhabiting insects that feed on the roots of seedlings show little preference for any particular tree species. Root bark beetles and root aphids are among the few that confine their feeding to the roots of certain host plants. White grubs, wireworms, root weevils, cutworms, and root maggots feed not only on the roots of forest seedlings but on the roots of many other plants. The stems of young seedlings may be attacked above ground by cutworms, grasshoppers, leafhoppers, and various bark-chewing beetles; and the leaves may be fed upon by caterpillars and sawflies and by vari-

ous scales, aphids, and bugs. Most of these insects, since they are enemies of larger trees as well, will be treated in later discussions.

While the control of insect pests in forest nurseries is sometimes a difficult matter, the nurseryman, at least, has measures at his disposal which would be impractical to use under forest conditions. Some root-feeding insects can be controlled by applying a fumigant to the soil, or by using poisoned baits, but much can be done to avoid injury through regulating cultural methods. Transplant beds which have become heavily infested should be plowed and allowed to remain fallow for a year. If they are cultivated often enough to prevent the growth of any weeds, most of the insects will have been starved out in a year's time, and the beds can be used again for a short period without serious injury to the transplants. Leaf-feeding insects usually are easily controlled by the use of sprays.

To protect seedlings from root-feeding insects after they are set out is not so simple, and, so far as is known, no attempt has been made to control soil-inhabiting insects in plantations or forests in the Western States.

KEY TO DIAGNOSIS OF INSECT INJURY TO SEEDLINGS

A. Roots of seedlings chewed, injured, or dying.
- 1. Rootlets completely bitten off or the bark badly chewed [3] by soil-inhabiting insects, appearing as
  - *a.* Curled, white grubs with three pairs of prominent legs and with brown heads [4] ______ white grubs, page 24.
  - *b.* Small, curled, white grubs with small brown heads but without legs [4] ________________ root weevils, page 26.
  - *c.* Long, slender, hard-shelled, yellow or brown "worms" with feebly developed legs [4] _______ wireworms, page 26.
  - *d.* Nearly hairless, soft, sluggish, dark-colored caterpillars working below surface of ground [4] cutworms, page 26.
- 2. Tunnels or borings under bark of larger roots root bark beetles, page 27.
- 3. Large, dark, soft-bodied aphids sucking sap from roots root aphids, page 28.

B. Stems of young seedlings badly chewed or injured.[5]
- 1. Stem bitten off, or bark badly chewed—
  - *a.* Nearly hairless, sluggish caterpillars working at night _______________________________ cutworms, page 26.
  - *b.* Grasshoppers_____________________ grasshoppers, page 164.
- 2. Borings under bark of larger seedlings________ bark beetles, page 96.

C. Leaves of seedlings either chewed, skeletonized, mined, discolored, or attacked by leaf-sucking insects___________________ defoliators, page 58.

WHITE GRUBS

White grubs (*29*) are probably more common in forest nurseries than any other soil-inhabiting insects. These are the larvae of June beetles (Scarabaeidae), which are widely distributed and feed on the roots of a great variety of plants. The adults are voracious feeders and in the Lake States and elsewhere are often very injurious to the leaves of plants.

[3] Damage meeting this description is done also by root-feeding mammals such as gophers, moles, etc.

[4] These characters are not specific and sometimes noninjurious larvae of similar appearance may be confused with these forms.

[5] Similar damage is often done by small animals, such as mice, squirrels, and porcupines.

The large, shining, brown "June bugs" (fig. 10) often lay their eggs in grassy places or where the ground vegetation is heavy. In the North, where the life cycle is 3 or more years in length, the small white grubs feed during the first summer on organic material and on small rootlets near the surface of the soil. As cold weather approaches they burrow more deeply into the soil and hibernate. The second season the grubs are larger and do their greatest damage to the roots of seedlings and small trees. They again hibernate over the second winter and again feed during the following spring. The full-grown grubs are white, thick-bodied, with dark-brown heads and three pairs of well-developed legs. They always lie in a tightly curled position and are familiar objects to everyone who has dug for fish bait. In midsummer of usually the third season they reach full growth, transform to the pupal stage within a cell in the ground, and emerge the following spring as full-grown beetles. In the Southern States the cycle may be completed in 2 years, or possibly less, while in the North and in Canada it may take 3, 4, or even 5 years.

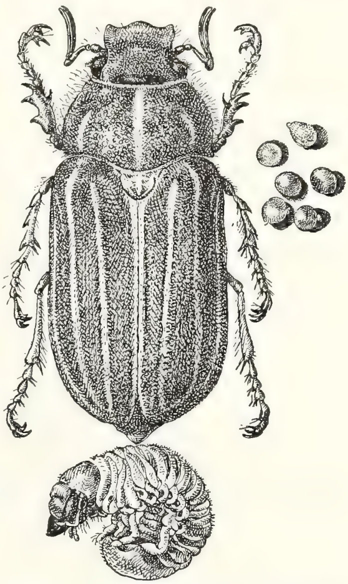

FIGURE 10.—Adult beetle, eggs, and larva or white grub of *Polyphylla crinita* Lec. × 2. (Drawings by Edmonston.)

The prevention of white grub damage can be accomplished to a great extent through modification of cultural operations. New ground that is to be used for nursery purposes should be put under cultivation for 2 or 3 years to allow for the emergence of beetles already in the ground and to avoid new egg laying.

If transplant beds are cultivated frequently in the seasons when they are lying fallow, and these periods of resting are interspersed between the period of use, the damage by white grubs will usually be comparatively light. Infestation in seedbeds is likely to give the most trouble, since the dense growth produces a favorable condition for egg laying, and the beds cannot be cultivated until the seedlings are taken up. Beds can be protected by covering them with a ¼-inch mesh wire screen during the egg-laying period. If the beds become infested, the young seedlings should be dug the second spring to avoid heavy damage. Clean cultivation, screening of seedbeds, and rotation of transplant beds are first steps in holding white grub damage to a minimum, but even these are not always successful.

Seedbeds which must be repeatedly used may become heavily infested. Recent experiments have indicated that the grubs can be killed by the use of 50-percent miscible carbon disulphide. A satisfactory dosage consists of 1 quart of the miscible carbon disulphide to 50 gallons of water and an application of 3 pints of the emulsion to each square foot of soil surface. Care should be taken not to allow any of the solution to come in contact with the leaves of the young

seedlings, and in hot weather a weaker emulsion should be used to prevent injury to the roots. While this treatment has given satisfactory results in the experiments so far conducted, it should not be adopted on a large scale until it has been demonstrated that it is applicable on the particular type of soil at the nursery, and puddling of the soil should be carefully avoided.

Treating some soils, especially light sandy loams, with arsenical compounds has been shown to be destructive to seedlings, and in many cases it has left the ground in a toxic condition for 3 or 4 years.

ROOT WEEVILS

In forest nurseries of the Pacific Northwest the strawberry root weevil has proved to be one of the most serious insect pests. Three species are involved in this damage—*Brachyrhinus ovatus* L., *B. rugosostriatus* Goeze, and *B. sulcatus* F.

The adults are small, brown, hard-shelled, wingless beetles about one-fourth inch in length, with head extended into a snout. When the adult weevils emerge in the early summer they migrate on foot, crawling everywhere, in search of suitable places for egg laying. Eggs are laid only at the root crown of plants, and the small, white, curled grubs develop in the soil, where they feed on the roots of various plants. The life cycle is completed in 1 year, and the full-grown larvae pupate in the soil and emerge as new adults the following summer.

Seedbeds can be protected from infestation by encircling them during the migration and egg-laying period with barriers, such as boards or metal strips placed on edge in the ground and painted with sticky substances, such as coal tar or sticky tree-banding material. Poisoned baits have also proved effective in destroying the weevils in larger fields. An effective poisoned bait consists of 5 pounds of powdered calcium arsenate and 95 pounds of ground dried-apple waste, applied at the rate of from 50 to 70 pounds per acre.

The most satisfactory method of control is through clean cultivation and rotation of seed and transplant beds, allowing infested plots to remain fallow and be cleanly cultivated in alternate years.

WIREWORMS

Under certain conditions wireworms (Elateridae) (*53*) may prove to be troublesome nursery pests. They are most frequently found in heavy, moist soil, where they feed on undecayed plant material and small roots. These long, slim, cylindrical, hard-shelled "worms" with feebly developed legs are the larvae of click beetles, which are most easily recognized by the layman by their ability to flip into the air for several inches when turned on their backs.

No satisfactory method of controlling wireworms has been developed, and soils which are abundantly infested with them should be avoided for nursery purposes.

CUTWORMS

From time to time cutworms make their appearance in forest nurseries and do considerable damage to the young trees by feeding on the roots or clipping off seedlings at the ground line.

The adults of cutworms are the dull-colored, yellow, tan, or brown moths which collect around lights at night and are commonly referred to as "millers." They fly at night, usually early in the spring, and lay their eggs on the ground where there is ample vegetation for larval food. The larvae or cutworms work underground, feeding on the roots of various plants, or during the night they often feed aboveground on the foliage or clip off the stems at the ground line. They are dull-colored, with very few or sometimes no hairs on the body, and some have a greasy, slimy appearance that is in keeping with their ground habitat. They reach full growth late in the summer or in the fall and overwinter in the soil as full-grown larvae or as pupae in earthen cells. Emergence takes place the following spring, or in some cases there may be several broods a year.

Clean culture in the nursery to avoid the establishment of weeds or ground cover that would be suitable for egg-laying, and cultivation in the fall and winter to destroy the hibernating larvae, will do much to prevent cutworm damage. Where such methods fail, poisoned baits made of bran and white arsenic are effective. A good formula for this purpose is as follows:

Wheat bran	25 pounds.
White arsenic or paris green	1 pound.
Blackstrap molasses	1 quart.
Water	1 to 2 gallons.

Where seedbeds can be flooded for a time without damage to the young trees, cutworms can be drowned. Such treatment is often both simple and effective.

ROOT BARK BEETLES

Although bark beetles (Scolytidae) are primarily enemies of large forest trees, a few species are of importance in killing large seedlings through attack on the roots. Species of the genera *Hylastes* and *Hylurgops* have been found doing this type of damage. Normally these are secondary bark beetles which breed in slash and under the bark of trees killed by fire or insects, but they appear to be primary in attacking the roots of suppressed or weakened seedlings. The attacking beetles make entrance burrows at the ground line and construct winding galleries which extend downward into the larger roots and are partly filled with frass. The larvae work through the cambium, away from the egg tunnels, and feed together without scoring the wood. Seedlings an inch or more in diameter are killed by the attacks. The species which have been found doing this type of damage are noted below:

Species	Hosts
Hylastes nigrinus Mann	Douglas fir, western white pine, western hemlock, and probably other conifers.
Hylastes macer Lec	Engelmann spruce, ponderosa pine, and lodgepole pine.
Hylurgops lecontei Sw	Lodgepole pine, ponderosa pine.
Hylurgops porosus Lec	Lodgepole pine, western white pine, and probably other pines.
Pseudohylesinus granulatus Lec	Balsam firs.

The general habits of bark beetles are more fully discussed in a later section (page 96).

ROOT APHIDS

Some aphids are root-feeders. One species, *Cinara* (*Lachnus*) *curvipes* Patch, was recently found feeding on the roots of small white firs in Oregon. The large carpenter ants (*Camponotus herculeanus* var. *modoc* Wheeler) were carefully tending them. The ants had gnawed the outer bark and cambium of the fir roots, and colonies of aphids were feeding on the fresh wounds. They were observed working the full length of their beaks into the cambium and feeding on the juices. This same aphid has been found working on the bark of twigs of balsam firs and *Cedrus atlantica.*

INSECTS INJURIOUS TO YOUNG TREES (SAPLINGS AND POLES)

Trees in plantations and forests are subject to attack by a great many insect pests while they are growing from saplings to maturity. After having been at first beset by the root-feeding insects, they are later attacked by another group of injurious insects—those which feed on the rapidly growing terminal shoots, laterals, tips, or buds. This type of damage seldom results in the death of the young trees, but it often seriously deforms or stunts them. As buds and terminals are killed the tree throws out new buds and shoots, which results in much branching. The tree becomes bushy in form, with the main trunk crooked and gnarled, and is often permanently ruined for commercial use. At this stage of the tree's life, leaf-eating and bark-feeding insects also begin to be of importance.

The control of insects affecting young trees rarely calls for the application of direct control measures. A certain amount of insect damage is normal in natural forests and is only a part of the natural thinning process. When an epidemic develops as the result of some disturbance of the natural balance, as through the creation of an abundance of slash, windfall, or fire-injured trees, some direct control action may be necessary to protect the younger trees. Usually the indicated remedy is avoidance of the conditions that induce epidemics or the prompt disposal of breeding material. In plantations, or in the case of trees of special value, some attention to insects may frequently be justified.

The control of terminal-feeding insects presents an extremely difficult problem. In general little can be done except through spraying, dusting, or hand-picking of damaged shoots and encouraging of parasites. The cambium-feeding insects can usually be controlled by felling and burning the infested material, and leaf-feeding forms can be controlled by spraying or dusting. Special methods adapted to the control of each group will be mentioned under later discussions.

KEY TO DIAGNOSIS OF INSECT INJURY TO YOUNG TREES

A. Terminal shoots, laterals, or tips deformed or killed. Trees weakened or stunted but seldom killed (except a few of the smaller seedlings).
  1. New or old twigs, branches, or succulent shoots killed. Insect tunnels or borings found under the bark.
    a. Point of attack showing a small pitch tube with exudation of fine boring dust. Under the bark or in pith are found small egg tunnels of uniform

width, free from packed boring dust, made by small brown beetles; and larval tunnels packed with fine borings made by small, white, curled, legless larvae---------------------- twig beetles, page 30.

b. Point of attack not conspicuous and not showing a small pitch exudation. Tunnels under bark, nearly round, free from pitchy exudations, filled with coarse or powdery boring dust. Made by small, white, curled, legless grubs-------- twig weevils, page 33.

c. Point of attack not conspicuous. Tunnels under bark broadly oval or nearly flat and filled with boring dust. Made by slender white grubs with broad heads---------------------------- twig borers, page 35.

d. Bark and wood of twigs conspicuously gnawed and girdled, causing death and breakage twig girdlers, page 35.

e. Point of attack showing resinous exudation, with larval castings webbed together, or pitch nodule. Resinous tunnels under bark or in the shoots made by active caterpillars twig moths or tip moths, page 37.

2. Leaves and buds at tips of branches webbed together and killed. Very little damage to other parts of the shoots bud moths, page 44.

3. Tips of branches appearing unhealthy, sickly, badly swollen and deformed, or killed. No borings under the bark.

a. Succulent tips covered with small, soft-bodied insects, or stems covered with powdery, cottony incrustations or shell-like scales; trees dripping a sticky exudation; often covered with a black smut sap-sucking insects, page 44.

b. Terminal shoots or leaves enlarged, galled, or swollen gall makers, page 52.

c. Twigs with dying and dead needle tufts, bark filled with resinous pockets containing small red maggots pitch midges, page 54.

B. Entire tree, or a large part, sickly, dying, or dead; foliage fading, turning yellow or red.

1. Tunnels or borings found under the bark of the main trunk or larger branches---------------------- cambium feeders, page 56.
2. Insects found feeding on the roots------------ root feeders, page 24.
3. Foliage fed upon, partially or wholly stripped from the trees, or appearing sparse and sickly------------- defoliators, page 56.

INSECTS AFFECTING TWIGS, TERMINAL SHOOTS, AND BUDS

Injury to leaf buds, succulent terminal shoots, and growing tips may be caused by insects of a number of different groups, such as twig-boring caterpillars, twig weevils, twig beetles, roundheaded or flatheaded borers, or even pitch midges, aphids, and scale insects (fig. 11). Such insects show a decided preference for these tender, growing parts of the trees. The damage they do to the new growth of older trees is of much less importance than that done to young trees in the formative stage. In the normal forest the damage of this character to native trees is rarely extensive enough to be of serious consequence, but on cut-over lands and in plantations it is frequently disastrous.

The seriousness of this type of damage is shown in the sand-hill plantations of the Nebraska National Forest. Two species of pine tip moths (*Rhyacionia* spp.), which were of little importance in their native habitat, found their way into these new isolated plantations. In the new environment, freed from their native parasites and find-

ing the newly planted trees nonresistant to their attacks, they proceeded to cause serious damage.

The control of insects that feed on twigs and terminal shoots presents many difficult problems, and under forest conditions little of a practical nature can be done to control them, after they have become established. Under management, however, much damage from this source can be avoided by growing trees in dense stands or by keeping the trees in as vigorous growing condition as possible.

Under special conditions, where the value of the young trees justifies the expense, control can be accomplished by hand picking the

FIGURE 11.—Group of young, thrifty ponderosa pines killed by scale insects. (Group killings of this type are most frequently caused by engraver beetles.)

infested shoots and either burning them or placing them in cages designed to retain the destructive species, but allow the escape of its parasites. Recently one or two projects of this character have been carried out with very satisfactory results. In the case of the isolated Nebraska sand-hill plantations much good was accomplished by introducing the native parasites of the tip moths.

TWIG BEETLES

The bark and pith of the smaller twigs, and branches of various coniferous and broad-leaved forest trees, are frequently mined by the smaller species of bark beetles of the family Scolytidae. These small twig beetles are often very abundant in the branches and twigs of dead, dying, or recently felled trees and in the twigs of healthy trees in the vicinity of slashings. Usually they confine their attacks to the twigs of trees of various ages and are commonly referred to as "twig beetles."

The attack of the twig beetles on living trees (fig. 12) is indicated by a small pitch tube or the exudation of fine boring dust at the point

of attack on the twig. Under this will be found small tunnels of uniform width, free from packed boring dust, which are made by small brown to black beetles. From egg niches along the sides of the egg tunnels, larval mines extend under the bark. These are made by small, white, curled, legless larvae that leave fine, packed boring dust behind them. In many cases several egg tunnels start from a circular entrance chamber under the bark and run lengthwise of the stem.

This type of work may be done by members of several genera of bark beetles represented by hundreds of species, so only a few of the more common species can be mentioned here. Moreover, there is no well-defined dividing line between the species that work in twigs and those that work in the larger limbs, branches, and trunks. Some species may be found breeding in all of these places; so, in addition to the species listed in this section, those described under the heading of "Bark beetles" on page 96 should also be considered.

The control of twig beetles has never been attempted in western forests, as their damage is seldom serious enough to warrant control measures. If they are especially bad in plantations or on shade trees, pruning the infested branches and buring the twigs may be of some benefit.

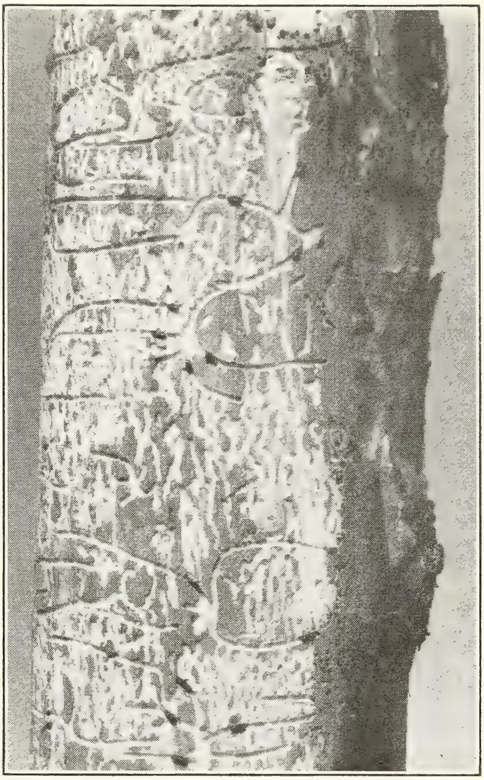

FIGURE 12.—The Douglas fir twig beetle (*Pityophthorus pseudotsugae* Sw.) and character of its work in mountain hemlock. Natural size.

PINE TWIG BEETLES

There are a large number of twig beetles that work under the bark and in the pith of pine twigs and sometimes in larger branches and even in the trunks. These species develop readily in slashings and broken twigs, and frequently cause the death of twigs and limbs on living trees. The twig beetles most frequently found attacking pines belong to the genera *Pityophthorus*, *Pityogenes*, *Pityoborus*, *Pityophilus*, *Myeloborus*, *Carphoborus*, *Orthotomicus*, and *Ips* (p. 110).

The typical work of the *Pityophthorus* (5) consists of a central nuptial chamber under the bark, from which radiate several egg galleries each occupied by a female beetle (fig. 13). Eggs are placed in large niches along the sides of these egg galleries, and the larvae, on hatching, work through the cambium of the twig and, on reaching

full growth, pupate at the end of the larval mines. There are usually two or more generations of the beetles each year, the number varying with the locality. As over 100 species have been described from western pines, no attempt will be made here to list or segregate them.

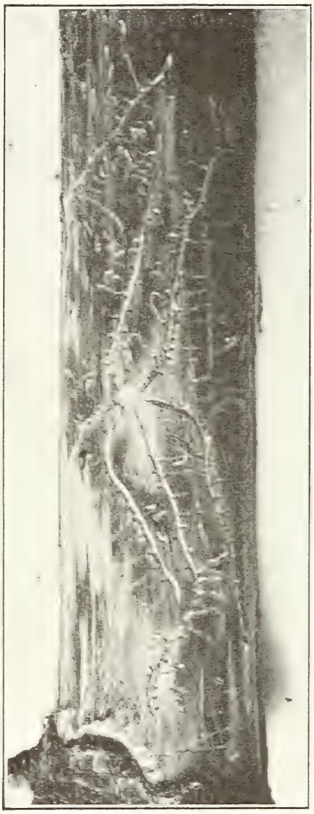

FIGURE 13.—Typical galleries of a pine beetle (*Pityophthorus nitidulus* Mann.) Natural size.

The species of *Myeloborus* (5) construct their egg tunnels principally in the pith of pine twigs. The larvae bore into the wood, without making definite larval mines, and so destroy the interior of the twig as to cause its death. In general their work is beneficial in that the death and dropping of lateral branches leaves the trunk of the tree freer from knots. In some cases, however, they are injurious to small trees.

Fir Twig Beetles

Twigs of Douglas fir and the balsam firs are frequently attacked by several species and genera of twig bark beetles. These usually are secondary enemies, attacking dying or felled trees, but occasionally they have been found attacking small standing trees in crowded stands. The most common species found in twigs belong to the genera *Pityophthorus*, *Pityokteines*, *Carphoborus*, *Cryphalus*, *Crypturgus*, *Pseudohylesinus*, and *Scolytus*.

Species of *Pityophthorus* and *Pityokteines* make a central nuptial chamber from which several egg galleries radiate. One of the most common species is *Pityophthorus pseudotsugae* Sw. (fig. 12). Another common species found attacking balsam firs is *Pityokteines elegans* Sw. The adults of both species are about one-eighth of an inch long, and the females have long, yellow hairs on the front of the head.

Twig beetles attacking spruce and hemlocks usually belong to the genera *Scolytus*, *Pityophthorus*, *Pseudohylesinus*, *Pityokteines*, or *Ips*.

Cedar Twig Beetles

Small twig beetles belonging to the genus *Phloeosinus* are commonly found working in the twigs and limbs of cedarlike trees, but they rarely are numerous enough to cause any appreciable damage. In the limbs and twigs of incense cedar are found *P. hoppingi* Sw., *P. antennatus* Sw., *P. fulgens* Sw., and *P. vandykei* Sw. *P. nitidus* Sw. works in Alaska cedar. *P. swainei* Bruck works in the twigs of Sargent cypress in California.

In addition to breeding under the bark of twigs and branches, adults of the larger species of *Phloeosinus* have the feeding habit of nipping off the leaflets and of feeding by boring into the small twigs of various cedars and cypresses. This injury is frequently very severe in the case of ornamentals and shade trees.

Broad-leaved trees are attacked by various genera of bark beetles, including many species of Micracinae. Oak twig beetles belong to the genus *Pseudopityophthorus* (p. 132).

TWIG WEEVILS

Twig weevils, belonging to the family Curculionidae, are often the cause of serious damage to the terminals of young coniferous trees. The adult female weevil uses her long, curved beak to excavate a small pocket in the bark of the terminal shoot in which to place her eggs. The young larvae, on hatching, burrow beneath the bark and excavate winding tunnnels between the bark and wood. On reaching full growth each constructs an oval cell, partly in the wood and partly in the bark, in which to pupate. Weevil work is distinguished from that of the twig moths in that there is little exudation of resin or pitch, and such as does occur is not mixed with webbing or larval castings to indicate the presence of the insects under the bark. The first conspicuous evidence of injury is the dying of the terminal shoot.

The two most important genera concerned are *Pissodes* and *Magdalis*. In the East the white pine weevil (*Pissodes strobi* Peck) is a well known example of the importance of these insects. In the Western States there are several species which do similar damage; though not of economic importance as yet, they are almost sure to be so when second-growth stands and plantations are more widely established.

Proper silvicultural methods offer the best solution of the weevil problem. Where young trees are grown in dense stands, or under the shade of other trees, weevil injury may be negligible. If in handling young stands subject to weevil injury the shade of older trees can be provided until the young trees reach 25 feet in height, or if the young trees can be grown in dense stands until they have passed the susceptible period, the damage should be lessened. In plantations, where individual care can be given, control can be obtained by cutting off the infested stems in May and September and storing these in wire cages of a mesh small enough to hold the beetles but large enough to allow the parasites to escape. If this is done for several seasons almost complete control of the weevils should be obtained.

The Sitka spruce weevil (*Pissodes sitchensis* Hopk.) is the insect most injurious to Sitka spruce reproduction in the Northwest. The small weevils attack and kill or seriously injure the terminal shoots of many young trees, causing a crook in the trunk or a forked and worthless tree. Trees from 2 to 8 inches in diameter and 5 to 25 feet in height are the most susceptible to attack. The species is distributed throughout the range of Sitka spruce.

The adults are light to dark brown, oval-shaped beetles, about three-sixteenths of an inch in length, with a prominent curved beak.

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Late in the spring and in the early part of the summer the adults feed on the tender bark of the previous year's terminals and with their beaks make little cavities in which eggs are laid. The young larvae, which are white, legless, curled grubs, work down the stem, boring through the bark and into the wood. Upon reaching maturity

FIGURE 14.—The lodgepole terminal weevil (*Pissodes terminalis*): *A*, Grubs in terminal shoots; *B*, weeviled tip showing emergence hole; *C*, adults, natural size.

they form in the wood or pith an oval cell lined with shredded wood fiber in which to pupate. There appears to be only one generation a year, but some of the insects transform in the fall of the year and others change and emerge the following spring. The winter is passed in all stages except the egg. Upon emergence the new adults do some feeding on the fresh bark of the terminal shoots and make numerous small feeding punctures, which later heal over with a bit of resin. No effort has yet been made to control this species.

Similar in habits and appearance to the above is the Engelmann spruce weevil (*Pissodes engelmanni* Hopk.). It works in the terminals of Engelmann spruce throughout this tree's range, in the Rocky Mountain region and the Pacific Northwest.

The lodgepole terminal weevil (*Pissodes terminalis* Hopp.) (*71b*) mines through the pith of lodgepole pine terminals (fig. 14) and kills them down to the first whorl of branches. It is particularly destructive in open-grown stands of young lodgepole pine in California.

Other species of *Pissodes* which work in the terminals of young trees include the following:

Species	Hosts and distribution
Pissodes yosemite Hopk	Ponderosa pine, western white pine, and sugar pine. California, Oregon, and Washington.
Pissodes schwarzi Hopk	Ponderosa pine. Rocky Mountain region.

Certain species of the genus *Magdalis* are also twig borers during the larval period (fig. 15). The adults feed on the foliage and make punctures in the twigs of conifers and broadleaved trees, in which eggs are deposited. The grubs burrow beneath the bark and cause the death of small branches and terminal twigs. The larvae are white, legless, and curled and are practically indistinguishable from those of *Pissodes*, but the work is usually distinct in that the larval borings are fine-grained and powdery instead of shredded, and the pupal cells are oval and smooth, without the lining of shredded wood fiber. The adults are bright blue, green, or black, with prominent curved beaks. Western species include the following:

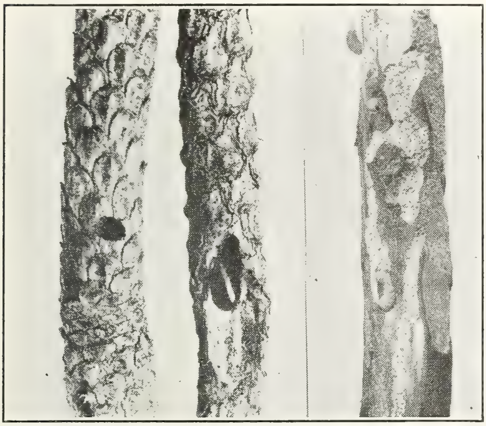

FIGURE 15.—Pine twig weevils (*Magdalis lecontei*), natural size.

Species	Hosts and distribution
Magdalis lecontei Horn (fig. 15)	Pines. Pacific States.
Magdalis cuneiformis Horn	Ponderosa pine. Western States.
Magdalis hispoides Lec	Lodgepole and other pines. Maine to British Columbia, New Mexico, and California.
Magdalis gentilis Lec	Jeffrey pine. California.
Magdalis proxima Fall	Monterey and probably other pines. California and Oregon.
Magdalis alutacea Lec	Spruce. Colorado and other Western States.
Magdalis gracilis Lec	Fruit trees and broadleaved trees. California, Nevada, and New Mexico.
Magdalis aenescens Lec	Alder and apple. Alaska to California and eastward to Montana.

TWIG BORERS AND GIRDLERS

A few bark and wood boring insects (*40*) belonging to the families Buprestidae and Cerambycidae are of some importance as twig borers, or girdlers, in various forest, park, and shade trees.

Beetles of the family Buprestidae lay their eggs on the bark of twigs, and the larvae, which are referred to as "flatheaded borers" on account of their horseshoe-nail appearance, work under the bark and into the wood, forming nearly flat tunnels filled with boring dust. The larvae are slender and white, without legs, and the enlarged forward segment of the body has horny plates on both the

top and lower side. Species which attack the twigs of coniferous trees usually belong to the genera *Anthaxia*, *Chrysophana*, *Chrysobothris*, or *Melanophila*. There are many small species of flatheaded borers which mine under the bark and kill the twigs of broadleaved trees. Some of the most striking work of this character is done by species of *Agrilus*, which make spiral girdles in the twigs

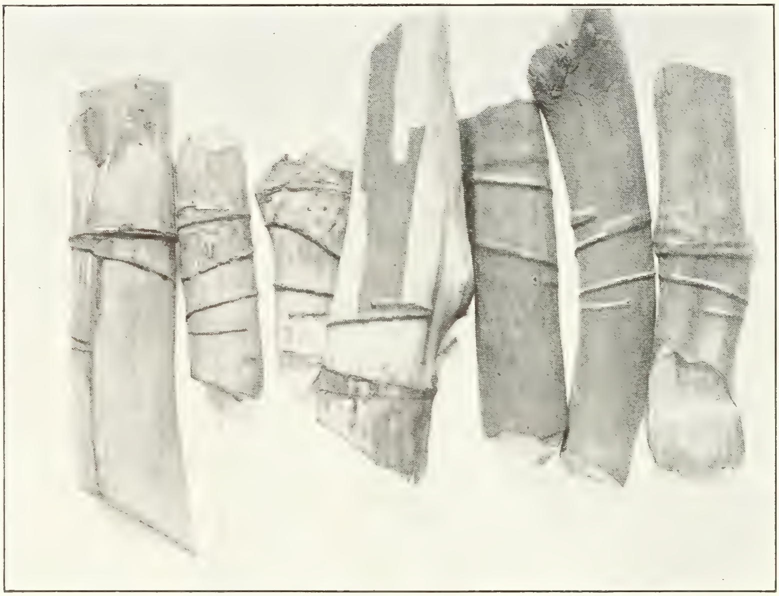

FIGURE 16.—Spiral twig girdling is characteristic of *Agrilus*.

of oak, birch, willow, and other broadleaved trees (fig. 16). Some of the western flatheaded twig borers and girdlers include the following:

Species	Hosts and distribution
Anthaxia aeneogaster Cast	Pines, firs, cypress, redwood, oak, willows, and other forest and shade trees. Western States.
Chrysophana placida Lec	Pines, firs, cedars, and hemlock. All Western States.
Chrysobothris mali Horn (*15*)	Alder, ash, aspen, beech, maple, poplar, willow, and many other hardwoods. Throughout the Western States.
Chrysobothris femorata F. (*15*)	Alder, ash, aspen, oak, poplar, willow, maple, beech, and many other hardwoods. Throughout the United States.
Agrilus angelicus Horn	Oak. California.
Agrilus politus Say	Alder, willow, and other broadleaved trees and shrubs.
Agrilus anxius Gory	Birch, willow, and aspen. Eastern States and west into Colorado and Idaho.
Agrilus bilineatus Web	Oak and chestnut. Eastern States and west into Colorado.

The adult long-horned beetles of some species of the family Cerambycidae girdle the limbs and twigs of various hardwoods and thus prepare them for the feeding of the larvae. These roundheaded

borers are very similar to flatheaded borers, except that the body is usually thicker and has a horny plate only on the upper surface of the first enlarged segment. The larvae feed under the bark and through the deadwood of the killed twigs, forming broadly oval tunnels which are filled with boring dust. The beetles that are most frequently involved in this type of damage are the following:

Species	Hosts and distribution
Oncideres trinodatus Casey	Mesquite, huisache, huajilla, and *Parkinsonia*. Texas, New Mexico, and Arizona.
Oncideres quercus Skinner	Oak. Arizona.
Oncideres pustulatus Lec	Mesquite. Texas, New Mexico, Arizona, and California.

Other species of roundheaded borers which may be found in twigs and branches of western forest trees include the following:

Species	Hosts and distribution
Opsimus quadrilineatus Mann	Spruce, fir, hemlock, and Douglas fir. Western States.
Oeme costata Lec	Ponderosa and piñon pine. Colorado and Arizona.
Oeme strangulata Horn	Cypress and juniper. Arizona.
Callidium hirtellum Lec	Ponderosa pine. California and Oregon.
Callidium hardyi Van D	Douglas fir, fir. Pacific coast.
Callidium californicum Casey	Juniper and cedar. Oregon, California, and Nevada.
Callidium pseudotsugae Fisher	Douglas fir. California and Oregon.
Neoclytus muricatulus Kirby	Spruce, larch, Douglas fir, and pines. Western States.
Pogonocherus oregonus Lec	Fir. Western States.
Pogonocherus crinitus Lec	Oak. California to British Columbia.
Oberea ferruginea Casey	Willow. Colorado.

TWIG MOTHS AND TIP MOTHS

The caterpillars of a large group of moths bore into and feed on the fresh, tender bark, and cambium layers of growing terminal and lateral shoots. Their feeding causes the deformation or death of these parts and results in a many-branched, poorly shaped tree, and in some instances results in the tree's death. Such damage is particularly serious in young plantations or to cut-over lands where a second crop of straight, vigorous trees which will produce sound lumber in the shortest possible length of time is desired. Older trees also are attacked by these moths, but the damage is much less conspicuous and of little significance.

Damage of this type is caused principally by the caterpillars of moths belonging to the genera *Dioryctria* and *Pinipestis* of the family Pyralidae and the genera *Rhyacionia*, *Petrova*, *Eucosma*, and *Laspeyresia* of the family Eucosmidae.

The control of cambium-feeding twig and tip moths is a very difficult undertaking, and as yet no completely satisfactory methods have been evolved. Spraying with a light miscible oil in May, at the time the eggs are hatching, has given fair results, but the time of application is such an important consideration that the method should be used only with the advice of an expert. The use of other sprays is still in the experimental stage. Hand picking of the infested tips offers some hope of control on small valuable plantations that are isolated from sources of reinfestation.

Pitch Moths

While in the caterpillar stage the pitch moths, belonging to the genus *Dioryctria*, bore into the cambium of trunk, branches, and twigs or into the fresh green cones of pines, Douglas fir, balsam fir, and spruce. The entrance to the tunnel is usually indicated by webbed larval castings. If the tree offers resistance to attack a copious flow of pitch forms a resinous mass at the entrance. The damage results in serious injury or death of the parts affected or even death of the entire tree.

The ponderosa pitch moth (*Dioryctria ponderosae* Dyar) causes considerable injury in the plantations of the Nebraska National Forest, where it attacks ponderosa, Scotch, Austrian, jack, and Norway or red pines. Most of the trees attacked are under 8 inches in diameter, and the bole and tops are frequently girdled by the larval tunnels. This damage is particularly serious in the case of the two European species, Scotch and Austrian pines. This insect is probably distributed through most of the Western States, having been recorded from Nebraska, Montana, and northern California.

The adults are blackish-gray moths with a wing expanse of nearly 1¼ inches. There are two narrow W-shaped bands extending across each forewing; the hind wings are dusky white. The moths appear from late in July to early in September and deposit eggs singly on the under side of bark scales, on trunk, or branches. The small larvae hatch in from 1 to 4 weeks, depending upon the temperature, and spin small hibernacula under bark scales, in which they overwinter. The first evidence of attack appears the following spring in the form of a small quantity of larval castings on the bark surface, followed by an exudation of pitch from the entrance hole. The larvae feed in the cambium region and construct irregularly shaped galleries beneath the bark. Some of these are rounded cavities with short side galleries, while others extend for several inches around the tree. The mature larvae are about 1 inch in length, usually light brown, though occasionally with a greenish tinge, and the bodies are marked with about six rows of small, dark-brown dots or tubercles. These larvae spin white papery cocoons in the burrows, or sometimes in the dried pitch mass near the surface, in which pupation takes place in July. The new adults leave the pupal skins in the cocoons and force their way through exit holes previously prepared by the larvae but concealed by flakes of bark or small webs. Control has been attempted by spraying the infested part of the stems with orthodichlorobenzene, diluted 1 to 5 with water, to which a small quantity of soap and linseed oil was added. The results were only partially satisfactory. Winter cutting and removal of the most heavily infested trees in the plantations resulted in a considerable reduction in the infestation. Control measures, however, are still in the experimental stage.

Dioryctria xanthoenobares Dyar is a golden-brown moth about three-fourths of an inch in length, which in the caterpillar stage attacks the twigs and cones of ponderosa and knobcone pines and possibly other pines. The caterpillar is pinkish and about 1 inch in length when full grown. It is known in California, Oregon, Washington, and Nebraska.

Dioryctria abietella D. and S. is a gray moth about three-fourths of an inch in length. The reddish caterpillars feed in the twigs and cones of knobcone, lodgepole, western white, sugar, and ponderosa pines, and many of the balsam firs. There appear to be two annual generations.

The Zimmerman pine moth (*Pinipestis zimmermani* Grote), a medium-sized moth, light to reddish gray, closely related to the above, is reported by Brunner (*9*) as being destructive to all coniferous trees, especially ponderosa pine, throughout the Pacific Northwest. He credits the "spike top" of mature trees and the spike top, stunting, and destruction of smaller trees, to the work of this insect. However, its importance has probably been greatly overemphasized, as its damage is usually negligible in most localities.

PINE-TIP MOTHS

The pine-tip moths belonging to the genus *Rhyacionia* may cause considerable damage to new leaders and shoots of young pine in localities where heavy infestation occurs, especially in plantations or on cut-over lands where trees are openly spaced and growing on sunny exposures. Trees from seedling size up to a height of about 25 feet are the most susceptible to injury. The small moths are yellow, gray, or reddish brown. They lay their eggs on the pine needles, and the young caterpillars start feeding at the tips of shoots, burrowing into the buds and down into the new growth. Their work is characterized by a resinous exudation at the point of attack, but they do not form a pitch nodule on the stem. Though trees are seldom killed, they are often deformed or forked, and height growth is retarded. Several species have been described from the Western States, where they normally work on the tips of young forest trees. Two species are particularly destructive in the pine plantations of the Nebraska National Forest.

Rhyacionia frustrana bushnelli Busck (*28*, *38*, *83*) causes a limited amount of damage to seedlings and saplings in its native range in the Black Hills, the Lake States, and northwestern Nebraska but has done serious damage where introduced in the isolated pine plantations of the Nebraska National Forest. In the ponderosa pine plantations of this forest about 90 percent of the leaders have been injured annually for many years by this tip moth. The adult moths are small, with a wing spread of about one-half inch. The front wings are mottled with yellowish gray and reddish brown. The larvae are yellowish and when full grown are nearly a half inch long. A single generation occurs in the Black Hills, the moths flying late in May and early in June to lay their eggs on the pine needles, and the larvae feeding during June and July. In Nebraska two generations develop annually, the moths flying in April and May and again late in June and early in July. The winter is passed in the pupal stage in cocoons spun by the larvae in the litter or soil.

Rhyacionia neomexicana Dyar has caused considerable injury to ponderosa pine seedlings and saplings at various places in the Southwest and is becoming a serious pest at present in the Nebraska National Forest plantations. It is known to occur in New Mexico, Arizona, southern and eastern Colorado, the Black Hills, and Ne-

braska. The moths measure about 1 inch in wing spread. The base of the front wings is dark gray and the outer third reddish orange. The larvae, when full grown, are nearly three-fourths of an inch long and reddish. There is but one generation annually. The moths fly in April and May in most localities, but in the latter part of May and early in June in the Black Hills. The full-grown larvae leave the tips during July and spin cocoons, usually in the bark crevices on the base of the tree below the litter. Here they transform to pupae and pass the remainder of the season and the winter. Infested tips can be identified, after the larvae leave, by the dead, partially developed needles toward the apex of the shoot, and by the fact that this part of the shoot, and usually the buds, have been riddled by the larval burrows and crumble readily when dry.

Rhyacionia pasadenana Kearf. is a silver-gray moth with reddish markings and a wing spread of five-eighths of an inch. In the caterpillar stage it bores through the buds and twigs of Monterey pine, ponderosa pine, and probably other pines in California, causing a pitchy exudation and the deformation or death of the terminal growth. It has recently been found attacking ponderosa pine seedlings and saplings up to 6 feet in height, where these are growing in open stands unshaded by mature trees, on cut-over lands in eastern California.

Rhyacionia montana Busck does similar injury to the buds and twigs of lodgepole pine in Idaho and Montana.

Pitch Nodule Moths

The pitch nodule moths belonging to the genus *Petrova* (*Evetria*), while in the caterpillar stage, bore into both the new and old growth of pine stems, twigs, and branches. Their work is characterized by a nodule or round dirty lump of pitch and frass which is formed at the point of attack. They do not attack the buds but usually work at nodes or whorls of branches, and finally pupate within the pitch nodule. Trees are seldom, if ever, girdled by the larval channels but often are so badly weakened that the tops are broken by wind or snow. The moths are speckled with brown, yellow, or gray markings and have a wing expanse of about three-fourths of an inch. The following species are found in the Western States:

Species of *Petrova*	Hosts and distribution
P. metallica Busck (fig. 17)	Lodgepole and ponderosa pine. California to Montana.
P. sabiniana Kearf.	Digger pine. California.
P. monophylliana Kearf.	Singleleaf piñon pine. California.
P. luculentana Hein.	Ponderosa pine. Colorado.
P. burkeana Kearf.	Sitka and Engelmann spruce. Washington and Montana.
P. picicolana Dyar	White fir and alpine fir. Washington.
P. albicapitana Busck	Lodgepole and ponderosa pine. Idaho and Montana.

Pine Pitch Moths

The caterpillars of the pine pitch moths, belonging to the genus *Eucosma* (*39*), bore through the pith of terminal shoots and leaders and cones of various coniferous trees. Owing to the drooping of the

dead lateral shoots the damage is often referred to as tip droop. The terminal leaders of young, thrifty trees are seldom killed, but the growth may be shortened. *Eucosma sonomana* Kearf. in the larval stage bores through the pith of the terminal twigs of ponderosa pine and Engelmann spruce. *E. bobana* Kearf. is an ochreous-colored moth with white spots on the forewings and a wing expanse of about 1 inch. The larvae have been found boring through the pith, cones, and seeds of ponderosa, Jeffrey, and knobcone pines in California and Oregon. *E. rescissoriana* Hein. is a dark brick-red moth with faint sprinklings of black scales. It has about seven-eighths of an inch wing expanse. The larvae feed through the pith and cones of lodgepole pine in California and Oregon.

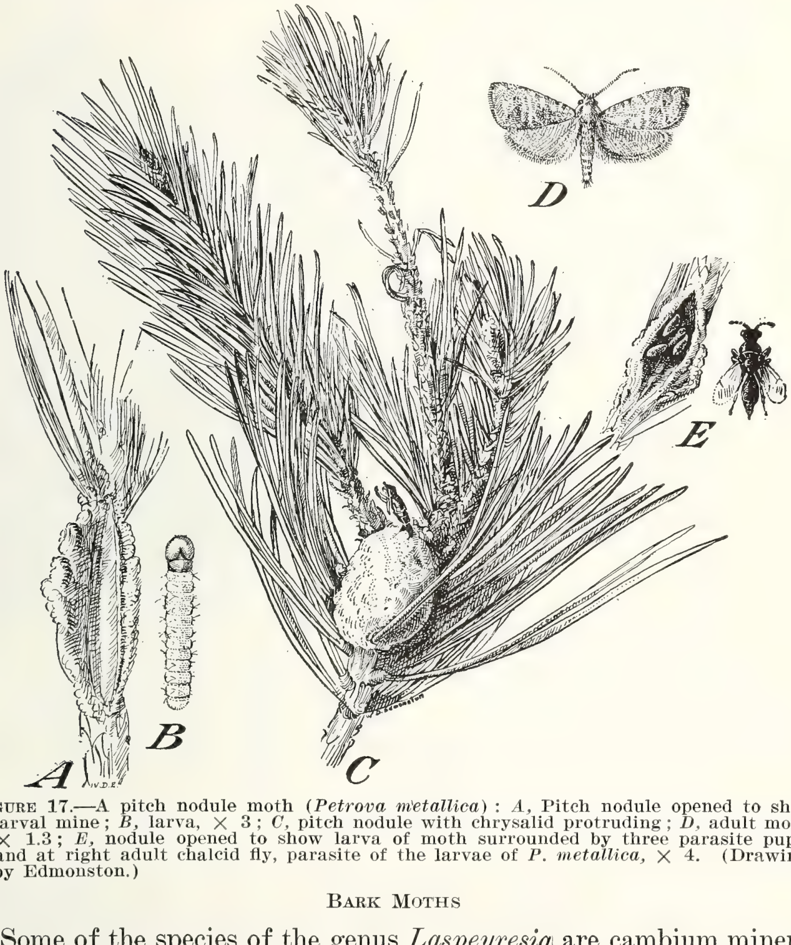

FIGURE 17.—A pitch nodule moth (*Petrova metallica*): *A*, Pitch nodule opened to show larval mine; *B*, larva, × 3; *C*, pitch nodule with chrysalid protruding; *D*, adult moth, × 1.3; *E*, nodule opened to show larva of moth surrounded by three parasite pupae and at right adult chalcid fly, parasite of the larvae of *P. metallica*, × 4. (Drawings by Edmonston.)

BARK MOTHS

Some of the species of the genus *Laspeyresia* are cambium miners, working in the bark of various coniferous trees. *Laspeyresia inopiosa* Hein. works in the bark of lodgepole pine in Idaho. *L. laricana* Busck feeds in the cambium of larch and Douglas fir. *L. leucobasis* Busck works in the bark of larch and Engelmann spruce.

L. populana Busck breeds in the bark of *Populus trichocarpa* in Montana and Colorado.

The cypress twig moth *Laspeyresia cupressana* Kearf. (fig. 18) is a small coppery-brown moth with a wing expanse of about five-eighths of an inch. The caterpillars, which are reddish green, bore into fresh green cones and into the bark of trunks and limbs of Monterey cypress in California. Usually the attack is made at the forks of branches or at points of injury. It causes an exudation of resin, and a deformation or the death of the affected part. In this work it probably plays a part secondary to that of a tree-killing bark disease, *Coryneum.*

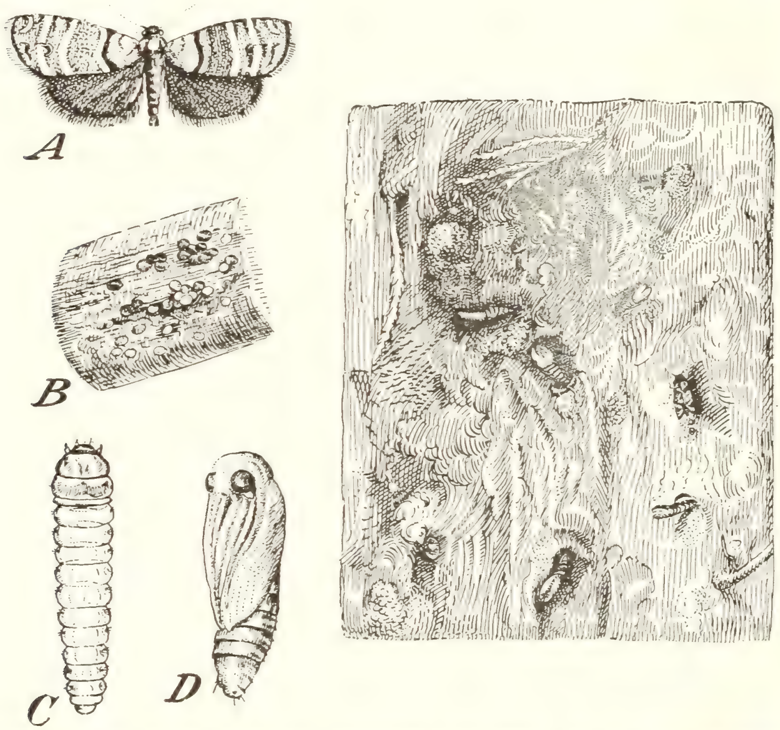

FIGURE 18.—The cypress twig moth (*Laspeyresia cupressana*) and its work in Monterey cypress: *A*, Adult, × 2.25; *B*, eggs, × 2; *C*, larva, × 3; *D*, pupa, × 3.75. (Drawings by Edmonston.)

CEDAR TIP MOTHS

The cedar tip moths, a group of small moths belonging to the genus *Argyresthia*, while in the caterpillar stage mine in the twigs and leaflets of the various cedar and cypresslike trees, causing the foliage to turn brown. The damage is not serious except to the appearance of shade and ornamental trees. Most of the feeding is done early in the spring. When the caterpillars reach full growth they emerge from the twigs and spin white, feathery cocoons on the surface of the leaflets; and in about 2 weeks the small moths emerge, fly, and lay their eggs in the crevices between the leaf scales. An oil and nicotine spray applied early in the spring is recommended for the

prevention of damage to ornamentals. Several western species of these moths have been described.

The cypress tip moth (*Argyresthia cupressella* Wlsm.) attacks Monterey and other species of cypress in central California. Two related species, A. *trifaciae* Braun and *A. franciscella* Busck, are

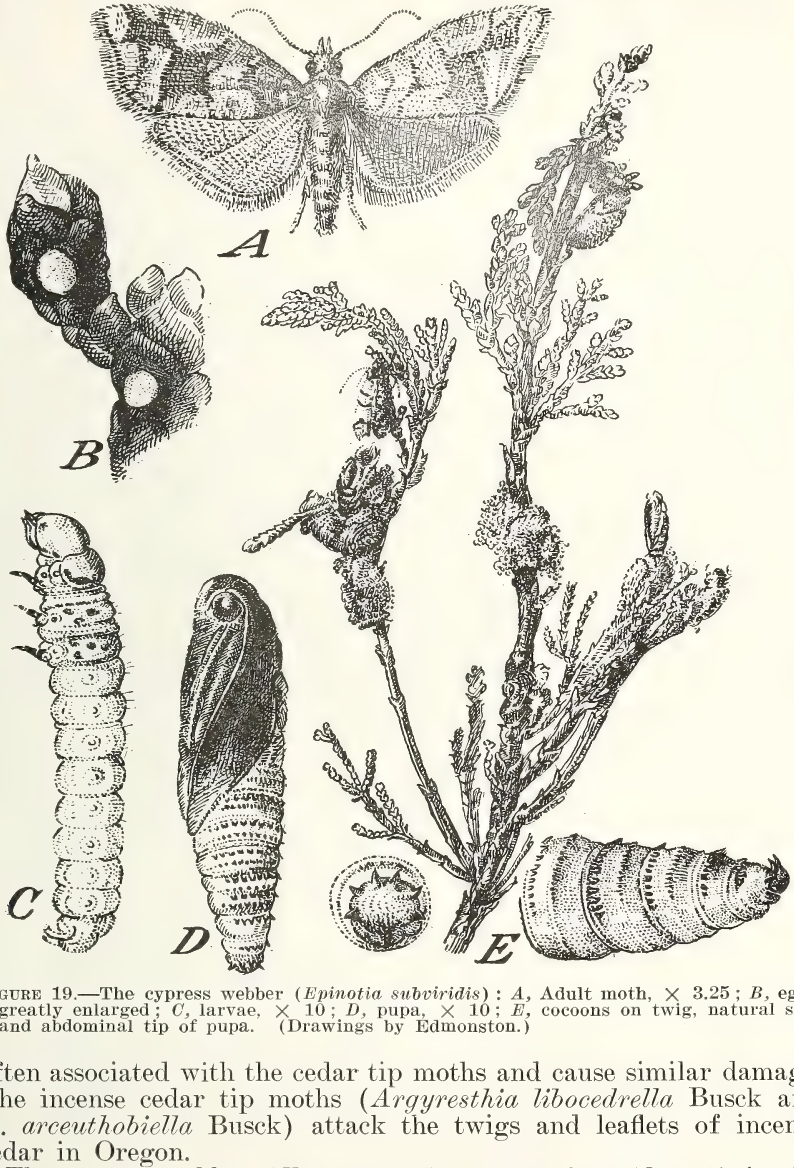

FIGURE 19.—The cypress webber (*Epinotia subviridis*): *A*, Adult moth, × 3.25; *B*, eggs, greatly enlarged; *C*, larvae, × 10; *D*, pupa, × 10; *E*, cocoons on twig, natural size, and abdominal tip of pupa. (Drawings by Edmonston.)

often associated with the cedar tip moths and cause similar damage. The incense cedar tip moths (*Argyresthia libocedrella* Busck and *A. arceuthobiella* Busck) attack the twigs and leaflets of incense cedar in Oregon.

The cypress webber (*Epinotia subviridis* Hein.) (fig. 19) in the caterpillar stage burrows through cypress leaflets, leaving a webby trail, and then ties bits of gnawed twigs and leaves together to form

a small nest. Its work causes the foliage of cypress to turn brown early in the spring. It is distributed through central and southern California and often is found working with the cypress tip moth.

BUD MOTHS

Frequently the tips of branches on young and older trees appear to be killed, but on close examination it is found that the twigs are not injured and the damage is confined to the buds, developing needles, or terminal leaves. These are webbed together to form a case, within which a smooth, hairless, very active caterpillar is found. Work of this character is done by a group of bud moths, mostly belonging to the family Tortricidae, which are true leaf eaters and therefore belong to the group of defoliators (p. 78). Usually their damage is confined to the leaves at the tips of branches, but during epidemics the older needles on the branches are also fed upon, and large forest areas may be completely defoliated and the trees killed. This group of bud moths, while it includes hundreds of species of only minor importance, also includes such conspicuous forest-tree defoliators as the spruce budworm, hemlock budworm, and lodge-pole pine needle tier.

SAP-SUCKING INSECTS

A large group of insects, such as bugs, aphids, and scales, belonging to the orders Hemiptera and Homoptera, and the mites and red spiders of the class Arachnida, which are closely related to insects, are equipped with slender beaks which they insert into the tender leaves or shoots of plants and feed by sucking the juices from these succulent parts. These various insects and mites are more important in the orchard and garden, or to shade trees, than they are in the forest. A few species, however, do noteworthy damage to small forest trees, and a few are important enemies of larger trees. Since, on the whole, they are more apt to be found seriously affecting young trees than older trees, they are considered at this time.

On shade and ornamental trees they can be controlled through the use of such contact sprays as lime-sulphur, miscible oils, or nicotine sulphate mixed with soap solution. Under forest conditions, however, the use of such sprays seldom is practical, and so far no control work of this kind has been undertaken in western forests.

KEY TO DIAGNOSIS OF SAP-SUCKING INSECT INJURY

A. Trees appearing sickly, leaves or stems not chewed but yellowing or covered with small incrustations, scales, powdery or cottony tufts, or small, soft-bodied insects. Trees frequently dripping with sticky exudation or covered with black smut.

1. Trees dripping with sticky exudation, black smut usually abundant. Colonies of small, soft-bodied bugs, usually with two cornicles or protuberances on rear of abdomen, appearing on leaves or tender stems ---------- aphids, page **45**.
2. Leaves yellowing in spots, or bent. Small tufts of cottony wax appearing on under sides of leaves adelgids and scales, pages **47, 49**.
3. Small, circular, oval, or elongated shells or scales on leaves or twigs. Black smut not usually abundant ----- scales, page 49.
4. Leaves yellowing, covered with fine, nearly invisible webs or silvery coating ------------------------ spider mites, page 51.

B. Trees appearing in fairly good health but leaves or stems badly stunted, galled, or swollen; sometimes with queer protuberances .... gall makers, page 52.
   1. Cone-shaped galls on terminal twigs of spruce .... spruce gall bark lice, page 47.
   2. Swollen twigs of white pine, covered with white incrustations .... woolly pine louse, page 48.
   3. Galls at base of pine needles causing premature shedding .... pine needle mite, page 52.

APHIDS OR PLANT LICE

Aphids are small, delicate, soft-bodied insects with pear-shaped or globular bodies and long legs. They range from almost colorless translucent to greenish or almost black. As a rule they are without protective covering and often occur in dense colonies on leaves or tender terminals of trees, where they feed by sucking the juices.

The aphids exude quantities of honeydew, which drips over the leaves and onto the ground beneath. This is a favorite food of ants, who cultivate and tend the aphids for it, and for this reason the aphids are often referred to as "ant cows." The honeydew also becomes a fertile medium for the growth of a black smut that covers the leaves, causing the trees to appear as if they had been sprayed with crude oil. Shade and ornamental trees are rendered particularly unsightly, besides being weakened by the aphid feeding; and forest trees are sometimes so weakened that after a season or two they die from the injury.

Aphids are remarkable because of their peculiar manner of development and the difference in the mode of reproduction of separate generations of the same species. They reproduce both sexually and also without mating, and both winged and wingless forms occur. The number of generations of aphids may vary from one or two to several in a single season, with more or less overlapping.

On shade and ornamental trees the aphids can be controlled by spraying the insects, when they are first observed, with a mixture of 4 or 5 pounds of fish-oil soap in 20 gallons of water, or with one-half pint of nicotine sulphate in 50 gallons of water in which 2 pounds of soap has been dissolved. Crude-oil emulsion and commercial lime-sulphur solutions are used as dormant sprays to kill the eggs. They are applied in the spring, about the time the buds begin to swell.

The spruce aphid (*Aphis abietina* Walk.) is by far the most destructive member of this group of sap-sucking insects that attack forest trees in the West. In recent years it has killed millions of feet of Sitka spruce along the tidelands of the Oregon and Washington coast (fig. 20) and the Columbia River, as well as having caused considerable damage to this conifer on the better inland sites. The wingless aphids occur early in the summer on the needles and tender growth of Sitka spruce. These insects are dull green and range in size from very minute young insects to full-grown winged aphids about three-sixteenths of an inch in length. Apparently this insect has an alternate host, disappearing from the Sitka spruce in midsummer, only to reappear again the next spring. No practical remedy has been suggested under forest conditions, but on shade and ornamental trees the pest can be controlled by spraying with

such contact insecticides as nicotine solutions, miscible oil, or lime-sulphur.

The Monterey pine aphid (*Essigella californica* Essig) is a small, light-green, pear-shaped insect about one-eighth of an inch in length and with very long hind legs. It is reported as feeding on the needles of Monterey pine, ponderosa pine, and Douglas fir in California and Oregon. *Schizolachnus piniradiatae* Davidson is a dark-green aphid, much smaller than the last named and covered with a cottony wax. This species attacks the needles of Monterey and other pines in central California. *S. tomentosus* DeG. is a yellow to brownish-black species which lives on the needles of ponderosa pine in Colorado. There are a large number of species that infest the leaves of various broad-leaved forest trees, but these are of little importance from the forestry standpoint.

FIGURE 20.—Sitka spruce along the Washington coast killed by the green spruce aphid (*Aphis abietina*).

BARK APHIDS

Large, long-legged, brown or dark-colored plant lice with naked bodies or lightly covered with a powdery wax belong to the genus *Cinara* (*Dilachnus*). They are frequently found feeding on the terminal twigs of coniferous trees, where they insert their beaks through the tender bark. The copious flow of honeydew causes a dense smutting of the trees, sometimes making them appear as if they had been sprayed with creosote. At times their work causes considerable injury.

The following species are recorded from the Western States:

Species of *Cinara*	Hosts and distribution
C. ponderosa Wms	Ponderosa pine and Jeffrey pine. California, Nevada, Idaho, and Colorado.
C. sabinianus Sw	Digger pine. California.
C. arizonica Wilson	Pine. Arizona.
C. edulis Wilson	Piñon pine. Colorado.

Species of *Cinara*	Hosts and distribution
C. schwarzi Wilson	Ponderosa and other pines. Arizona and Colorado.
C. pseudotsugae Wilson	Douglas fir. Oregon.
C. taxifolia Sw	Douglas fir. California.
C. braggi Gill	Blue spruce. Colorado.
C. caudelli Wilson	Spruce. British Columbia.
C. palmerae Gill	Engelmann and other spruce. Colorado.
C. picea Panzer	Spruce. California.
C. vandykei Wilson	Spruce. Washington.
C. ferrisi Sw	White fir. Northern California.
C. pacifica Wilson	Lowland white fir. Northern California.
C. occidentalis Davidson	White fir. Oregon and California.
C. burrilli Wilson	Juniper. Colorado and Idaho.
C. tujafilinus DelG	Aborvitae, cypress, and cedars. California.

Spruce Gall Bark Lice

Cone-shaped galls which form on the twigs of spruce trees are caused by several species of gall and bark lice belonging to the genera *Adelges* and *Pineus* (*1*) (formerly called *Chermes*). These galls frequently kill the terminals but rarely endanger the life of the trees and are of little importance under forest conditions. On seedlings and saplings in nursery or plantation, and on ornamental trees in gardens and parks, the formation of these galls is of more consequence, since they kill the tips of branches and tend to stunt and deform the trees.

Most of these insects have an alternate host tree upon which they appear in a different form. On pines and Douglas fir these alternate forms appear as a dirty white wax on the bark or as small tufts of cottony wax on the needles. Often these bark lice exude a honeydew upon which a black smut grows, and accumulations of this make trees very unsightly.

In nursery and plantation the gall lice can be controlled by cutting and burning the green galls before the insects have emerged in the spring, or by spraying the trees early in the spring, when the young begin to colonize on the new growth. For this purpose use a miscible-oil spray composed of 5 gallons of miscible oil, 1 quart of 40-percent nicotine sulphate, and 200 gallons of water.

Cooley's gall louse (*Adelges cooleyi* Gill.) is the species most frequently responsible for the formation of cone-shaped galls on terminal twigs of blue spruce, Engelmann spruce (fig. 21), and Sitka spruce in the West. Two or more other species do similar damage. The galls are from 1 to 2 inches in length, light green to dark purple, and are formed by the growing together of the basal portion of the needles so as to form chambers between the base of the needles and the stem. These chambers, which are not communicating, usually contain from 3 to 30 small wingless insects covered with a white waxy coating. These galls turn brown, dry, and hard on the trees after the insects have escaped, and they may persist for many years.

The alternate host is Douglas fir, on which these gall lice appear as small cottony tufts on the underside of the needles. Their feeding punctures cause the needles to turn yellow in spots. Sometimes the damage is so severe as to cause a browning and premature shedding of the foliage.

The seasonal history is very complicated. The form found on the Douglas fir needles during the winter represents hibernating females

or stem mothers. These lay eggs early in the spring, and the young, which settle on the tender fir foliage and feed, later mature into winged and wingless females. The wingless forms deposit eggs which hatch later into females that will hibernate, while the winged females migrate to the spruce and lay eggs at the base of the needles. The young hatching from these cause the formation of the cone-shaped galls. About the middle of July the forms in the galls become mature, full-grown, winged migrants which return to the Douglas fir to lay eggs that also produce hibernating females. Altogether there are five stages or forms in which these *Adelges* appear during different periods of their development.

FIGURE 21.—Galls formed on Engelmann spruce by Cooley's gall louse (*Adelges cooleyi*).

The species is distributed from British Columbia to California and eastward into Idaho, Montana, Wyoming, and Colorado.

Adelges oregonensis Annand appears as a small woolly louse on the twigs and base of needles of larch in Oregon, Washington, and Montana, but does little damage.

Adelges piceae Ratz. attacks the terminal twigs of lowland white fir and noble fir and causes a swelling to form around the bud, leaving it in a depression and making the twigs appear to end in a solid knob. This causes the trees to become badly gnarled.

Adelges tsugae Annand may be found on the needles and bark of western hemlock in California, Oregon, and British Columbia and appears as white cottony tufts.

The woolly pine louse (*Pineus pinifoliae* Fitch) (*Chermes pinicorticis* Fitch (*Chermes montanus* Gill.) is found in the Northwest from British Columbia to California and in Idaho, Montana, and Colorado, where it attacks blue spruce, Engelmann spruce, Sitka spruce, and western white pine. On spruce it forms loose terminal cone-shaped galls somewhat similar to those of *Adelges cooleyi*, except that the poorly formed chambers are intercommunicating and

contain only one or two young in each chamber, and when the insects emerge the galls flare open, and the scales drop from the twigs.

The alternate form attacks western white pine and is easily recognized by the waxy secretion that appears as a whitish-gray mold on the bark and needles. The attacked foliage is apt to be sparse and stunted; the needles fall prematurely, and the fascicles or bundle sheaths are left protruding from the limbs as short spurs. The damage is most frequently found on young white pines. In the last few years it has become a rather important enemy of white pine seedlings in eastern Washington, Idaho, and western Montana. The adults appear as little hemispherical, brown scales one-sixteenth of an inch in diameter, with a fringe of white hairs. The head and thorax are completely covered by this shield. The life history has not been thoroughly worked out, but is supposed to be as follows: Eggs are laid for the new generation early in the summer. These soon hatch and the young bark lice start sucking the juice from the white pine twigs. Part of these insects develop wings and fly to the spruce, where they construct the terminal cone-shaped galls. The others grow and reach the adult stage by the following spring.

Pineus boycei Annand makes similar galls on Engelmann spruce in Oregon and Montana. The needles with enlarged bases are pressed closely against the twigs and form intercommunicating chambers in which about 15 nymphs are found. The alternate host is not known.

Pineus borneri Annand feeds on the needles and twigs of Monterey pine in California.

Pineus coloradensis Gill. causes dense mats of dirty wax, covered with mold, to form on the twigs of various pines, including ponderosa pine, lodgepole pine, piñon, white pine, sugar pine, and single leaf piñon. It is found in Washington, Oregon, California, and Colorado.

Pineus similis Gill. is found forming cone-shaped galls on blue spruce and Engelmann spruce in Colorado, Oregon, and British Columbia. The galls are shorter and thicker than those of *Adelges cooleyi*, and the chambers are intercommunicating. An alternate host is not known.

SCALE INSECTS

(Coccidae)

Scale insects form one of the most abundant and variable groups of sap-sucking plant enemies. The young are mobile, small, and inconspicuous, but unlike most other insects, after they have become attached to a plant they lose all power of locomotion. They develop a hard epidermis, a thick waxy covering, or a round or oblong shell, and remain fixed in one position until they die. It is the female that causes all of the injury to plants. The adult males often have wings, eyes, antennae, and legs, but no mouth parts and so cannot take food. They live only for a short time and are rarely seen. A large number of species of scale insects infest nearly all forms of plant life, but only a few of those that feed on forest trees are of major importance.

Scale infestations on conifers, particularly those of the pine leaf and California pine scales, are often associated with conditions where dust and smoke occurs regularly in the atmosphere. Heavy scale attacks on ponderosa pine trees bordering dusty roads have been frequently observed as well as on trees exposed to air currents which

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carry the smoke from mills. The choking of stomata in the leaves by foreign particles probably renders them susceptible to these insects.

Scale insects are controlled through the use of contact sprays (*35*), such as miscible oils, distillate or petroleum emulsions, and in orchard work by fumigation. None of these methods are practical under forest conditions, but fortunately none of the scale insects attacking forest trees have become serious enough to call for control.

The pine needle scale (*Chionaspis pinifoliae* Fitch) (fig. 22) is probably the scale most commonly found on the foliage of western conifers. It occurs throughout the Western States, where it attacks all species of pine and sometimes Douglas fir, spruce, and cedar. Small trees, saplings, and poles, especially along dusty roads, are often so heavily infested that the foliage appears white. In some cases trees have been killed by the attack. The mature scales are small, nearly pure white, elongated, and about one-eighth inch in length. Eggs are laid in the fall and overwinter under the female scale. These hatch late in the spring, and the new scales became full grown by midsummer. An oil and nicotine spray will control this species if applied late in the spring when the eggs are hatching.

FIGURE 22.—The pine needle scale (*Chionaspis pinifoliae*).

The California pine scale (*Aspidiotus pini* Comst.) is often associated with the pine leaf scale in its attack on various pines, and it is also found in abundance on Douglas fir and hemlock and may attack other conifers. Many young pines in California have been killed by this scale. It is distributed over most of North America. The mature scales are almost circular, about one-sixteenth of an inch in diameter, and yellowish brown to black. The young hatch early in the spring and summer and settle upon the new needles of the host. From one to three generations are produced during the year, and the winter is passed in a half-grown condition.

Other common scales infesting western coniferous trees include the following:

Species	Hosts
Matsucoccus fasciculensis Herbert	Ponderosa and digger pines.
Toumeyella pinicola Ferris (fig. 23)	Monterey pine and other pines in California.
Physokermes insignicola Craw	Monterey pine.
Physokermes concolor Cole	White fir.
Physokermes coloradensis Ckll	Blue spruce in Colorado.
Aspidiotus ehrhorni Cole	Douglas fir and cypress in California.
Ehrhornia cupressi Ehrh. (*41*)	Monterey cypress.
Xylococcus macrocarpae Cole	Monterey cypress.
Aonidia shastae Cole	Bigtree in California.

Some of the mealybugs also attack forest trees. These are small, soft-bodied bugs covered with a white powdery wax. They are represented by *Pseudococcus ryani* Coq. on cypress, incense cedar, and redwood, and *P. sequoiae* Cole on redwood.

FIGURE 23.—The irregular pine scale (*Toumeyella pinicola*) on Monterey pine twigs. Natural size.

The foregoing is only a very brief and incomplete treatment of the scales and related insects which may be found attacking forest trees, since the species attacking various broadleaved trees (*42*) are too numerous to mention here.

SPIDER MITES

Another group of small animals of sap-sucking habits is that of the spider mites. Strictly speaking, these are not insects, since they have bodies divided into two segments instead of three and have four pairs of legs instead of three. However, since they are so closely related to insects, and their work is so similar, they are considered in this discussion. The damage resulting from their natural habit of sucking the juices from leaves and tender stems of various plants, including many ornamental, shade, and forest trees, is considerable. The leaves turn yellow and drop, and the trees attacked are often seriously weakened, rendering them susceptible to attack by tree-killing insects. This

type of damage, while important on shade trees, is seldom so on forest trees under natural conditions.

The pine needle mite (*Eriophyes pini* Nalepa) is a very minute yellow blister or gall mite which has been found causing considerable injury to the needles of Monterey pine in Golden Gate Park, San Francisco, and to Torrey pine and Jeffrey pine in other parts of California. It feeds within the basal sheath of the needle cluster and causes a premature shedding of the needles and a weakening of the tree. A 10-percent miscible-oil spray has given fairly satisfactory control, but the removal of badly infested pine may at times be necessary.

Red spiders (*Tetranychus* spp.) are frequently the worst enemies of shade trees in the central valleys of California, especially during long, dry, hot seasons, when they attack the leaves and cause them to fade and die. One species in particular is found on incense cedar and another on Monterey pine. Many species are found on the broad-leaved trees. Both sulphur dusts and the combination oil and nicotine sprays have given good control on shade trees. More than one application during a year is frequently needed.

Oligonychus americanus Riley has appeared as a rather common pest of Douglas fir along the Madison River of Yellowstone National Park. It webs the needles and turns them a dirty brown.

GALL MAKERS

A very large group of insects and mites have the unique ability to irritate various plants so as to produce a gall, swelling, or peculiar malformation. The common oak apple is a familiar example. Some galls take the form of large, globular protuberances, others take the appearance of buds or flowers, while some are simply an enlargement of the leaf or stem. These galls seldom are seriously harmful, however, and control measures are called for only where ornamental trees are made unsightly by such growths. On forest trees their presence can usually be ignored.

Galls may be formed by several groups of insects. The cynipids, sawflies, gall midges, and gall aphids include most of the gall-forming insect species. Gall mites of the family Eriophyidae are also responsible for a large number of peculiarly shaped galls on broad-leaved and other trees. Other important plant galls are formed by fungi and various parasitic plants.

On ornamental trees some of the gall-forming insects can be controlled by spraying at the proper season of the year, but for forest trees such treatment is impractical and seldom would be justified by the importance of gall damage.

There are innumerable types of galls on the various species of western forest trees (*32*), particularly on the broadleaved trees, such as poplar and willow. Space in this publication would not permit even the listing of the various species. However, a few of the more important gall insects on commercially important forest trees will be mentioned.

Key to the Recognition of Some Important Insect Galls

A. Galls formed on coniferous trees.
  1. Galls affecting pine needles.
    a. Needles greatly enlarged or swollen at the base — gall midges, page 53.
    b. Needles blistered within the sheaths, causing premature shedding — pine needle mite, page 52.
  2. Twigs with dying and dead needle tufts; bark filled with resinous pockets containing small red maggots — pitch midges, page 54
  3. Swollen twigs of western white pine covered with gray, cottony secretion — woolly pine louse, page 48.
  4. Cone-shaped galls on terminal twigs of spruce — spruce gall bark lice, page 47.
  5. Prickly, burrlike or conical galls on juniper — gall midges, page 53.

B. Galls formed on broadleaved trees.
  1. Galls inhabited by small, white, legless, apparently headless larvae — cynipid wasps, page 53.
  2. Galls inhabited by small pink or red maggots — gall midges, page 53.
  3. Galls inhabited by small bugs with cottony wax secretions — gall aphids, page 47.
  4. Galls inhabited by microscopic eight-legged mites — gall mites, page 52.

Gallflies or Cynipid Wasps

(Cynipidae)

One group of small, four-winged, usually somber-colored yellow to brown or black, antlike wasps are responsible for the formation of a great variety of galls on the different parts of various forest trees, but particuarly on the oaks. These galls may be large, round, and shiny, like the common oak apples, or very irregular in shape and spiny, or may consist of just a tiny swelling on leaf, twig, or root. The larvae that inhabit these galls are white, legless, and without a distinct head. There are over 200 species described from various plants in the Western States. Only a few, however, do any appreciable damage.

Gall Midges

The gall midges belonging to the family Cecidomyiidae are responsible for the formation of a great variety of small galls on many different forest trees and plants. The adults are tiny pink flies resembling mosquitoes and are called midges. The larvae are small pink or red maggots, without legs or definite head, but with a dark "breastbone." Almost any part of the tree may be affected, but most galls are formed on the needles or leaves, in the cones or seeds, or in the bark of twigs. A few species on forest trees are of some economic importance.

The Monterey pine midge (*Thecodiplosis pini-radiatae* S. and M.) works at the base of the newly formed needles of Monterey pine in central California and causes them to become swollen and shortened (fig. 24). Sometimes heavily infested twigs are killed and the ornamental value of the trees seriously impaired. Other species that produce swellings at the base of needles on pines include *Janetiella coloradensis* Felt on pines in Colorado and Utah, and *Thecodiplosis cockerelli* Felt on *Pinus edulis* in Colorado.

Apical, budlike swellings are formed on ponderosa pines in Colorado by *Contarinia coloradensis* Felt and *Dicrodiplosis gillettei* Felt.

Several of the juniper galls are caused by species of gall midges. *Walshomyia juniperina* Felt causes a slightly enlarged fruit of *Juniperus californica*, also a purplish, apical bud gall with three or four diverging lobes. *Oligotrophus betheli* Felt forms reddish, apical, conical galls on *Juniperus utahensis*. *Allomyia juniperi* Felt produces a prickly, burrlike bud gall with numerous short, nearly straight, leaves and none reflexed. *Rhopalomyia sabinae* Felt attacks juniper in Colorado and Utah and produces thick-walled, purplish, apical bud galls which split open in four sections when the midges emerge.

FIGURE 24.—Monterey pine needles galled by the Monterey pine midge (*Thecodiplosis pini-radiatae*). Insert, adult midge. × 5.

PINE PITCH MIDGES

Some of the pitch or gall midges attack the tender twigs or terminals of young trees and, by forming pitch pockets under the bark, either cause their death or the deformation of the wood. Their work can be recognized by the small pink or red larvae found imbedded in pitchy pockets or galls under the bark. The adults are frail, two-winged flies or midges resembling mosquitoes. Many of the western forms have not been named as yet.

The birdseye pine midge (*Retinodiplosis* sp. near *inopis* O. S.) is a common species in southern Oregon, where for many years it has killed the lateral tips of many young ponderosa pines (fig. 25). In some years this damage has been so severe as to deform and in some cases actually kill the trees. The damage is first noticeable very early in the summer, when the new lateral shoots fade, droop, and gradually turn yellow and die. In some cases nearly every new shoot is affected. On examination of the dying tips the bark will be found to be pitted with small resinous pockets, in each of which are small

bright-red maggots. If the pockets are not numerous enough to kill the terminal the injury heals over, but for several years the annual rings are distorted into a peculiar whorl until the pocket is completely

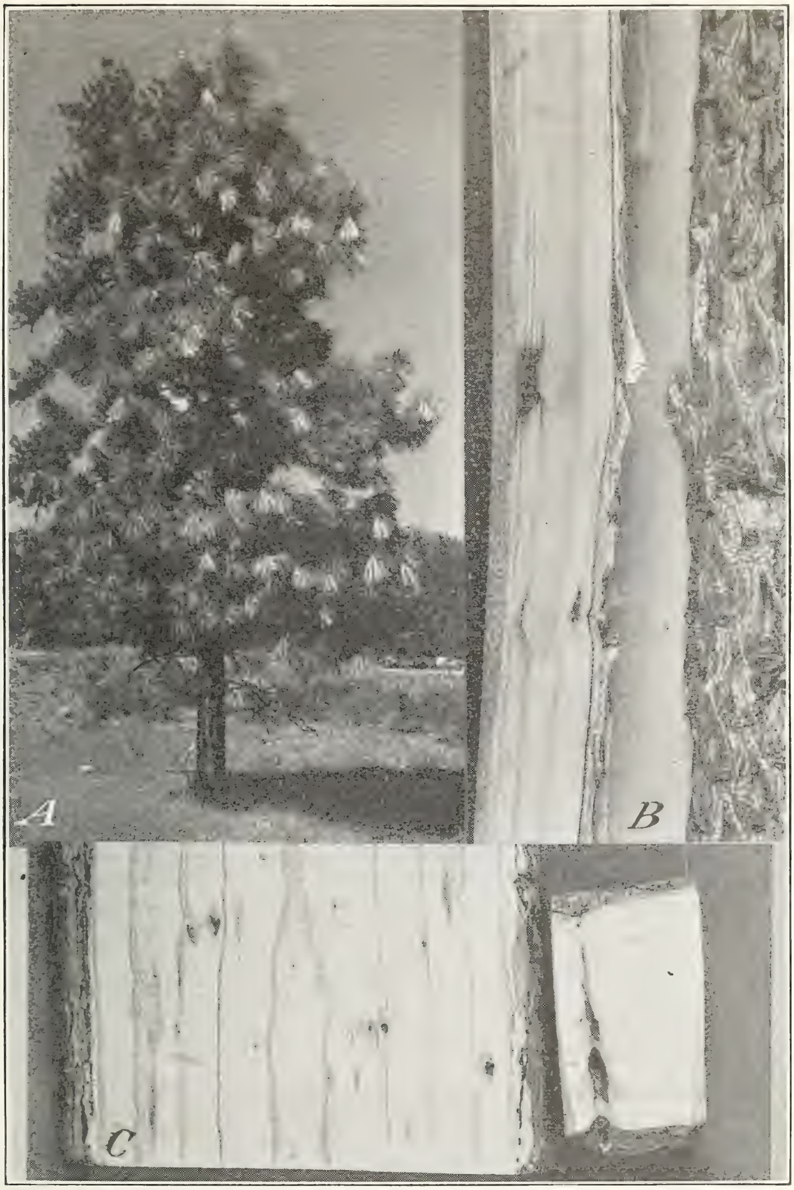

FIGURE 25.—Work of the birdseye pine midge (*Retinodiplosis* sp.) : *A*, Twig tips killed by midge attack ; *B*, pitch gall in cambium ; *C*, birdseye effect in pine lumber.

covered. This produces a defect in the grain of ponderosa pine lumber known as "birdseye pine" which actually enhances its value for finishing purposes.

The Monterey pine resin midge (*Retinodiplosis resinicoloides* Wms.) is another small pitch midge which inhabits the resin exudations of Monterey pine but apparently is not injurious to the trees.

FEEDERS ON THE INNER BARK OF YOUNG TREES

The most frequent damage to young trees by insects that feed on the inner bark is that suffered by intermediate or suppressed trees growing under crowded conditions or those weakened by drought, fire, or mechanical or other injury. Vigorous, young, dominant trees in the stand have a good chance to escape damage from these insects, except under conditions where they become epidemic. Usually the normal damage of this character in the virgin forests is of more benefit than otherwise, since it represents a natural thinning process and the release of the more dominant trees from competition. At times, however, such damage may become serious when outbreaks of bark beetles or other cambium- or root-feeding insects sweep through the young stands and kill a high percentage of thrifty as well as weakened individuals.

The insects which feed on the inner bark of trunk or roots of young trees are usually those which also feed on thin bark of older trees. These include certain groups of bark beetles, bark borers, and bark weevils. Since most of these insects do their greatest damage to older, mature trees they will be discussed later under another heading (p. 95).

Many species of bark beetles (Scolytidae) inflict their greatest damage on small or thin-barked trees. Many of these are rarely, if ever, primary and aggressive in their attacks upon large trees, but may breed in windfalls, slash, or large trees that are dying or have been attacked first by other bark beetles. Breeding in such trees or felled material, they may emerge in large numbers and become very destructive to the small trees in the stand.

In pines, the pine engraver beetles of the genus *Ips* are the ones most frequently responsible for this type of damage. Less frequently species of *Pityogenes* or *Pityophthorus* are involved.

In young stands of Douglas fir *Pseudohylesinus nebulosus* Lec. and *Scolytus unispinosus* Lec. frequently kill groups of small trees, particularly in the vicinity of slashings.

Small balsam firs are similarly affected by species of *Scolytus*, *Pseudohylesinus*, and *Pityokteines*. Young spruce and hemlock also may be killed by species of these and other genera.

Young redwoods, cedars, cypresses, junipers, and related cupressine trees are frequently killed by species of *Phloeosinus*, which breed in the trunks and limbs of dying or dead larger trees.

DEFOLIATORS OF YOUNG TREES

The insects that feed upon the leaves of young trees are in nearly every instance the same species as those that feed on the leaves of older trees. Defoliating insects usually show no particular choice as to the age or size of tree that they attack, and young trees in the forest may be fed upon by almost any leaf-feeding form. In some cases the young trees in the stand are actually avoided by defoliating insects. This was particularly noticeable in the case of the hemlock

looper outbreaks, where heavy defoliations ceased when stands of young growth were reached.

Since the damage done by defoliators to mature forest trees is usually of greater importance than that done to young trees, this group of insects will be discussed in the following section (p. 58).

INSECTS INJURIOUS TO MATURE FOREST TREES

The insects that prey upon young forest trees and that may, during the formative years, cause serious injury through stunting, deforming, or halting growth are of little importance after the trees have

FIGURE 26.—Ponderosa pines severely defoliated by the pine butterfly.

reached maturity. The mature trees may still be fed upon by root-feeding or terminal-feeding insects, but such damage within reasonable limits can be borne without fatal consequences, and the small loss in growth increment on mature trees is of minor importance. In general, there are only two large groups of insects that may bring about the death of mature trees, (1) those that feed on the leaves and cause severe defoliation and (2) those that bore into the inner bark of the main trunk and cut off the supply of moisture and food.

In many ways the defoliators are the most dangerous. They are primary and aggressive in their activities and attack healthy, vigorous trees as quickly as undernourished, weakened ones (fig. 26). The injury they cause does not always result in the immediate death of the tree but often so greatly weakens it that it becomes readily susceptible to bark-beetle attack. On the other hand the miners of the

inner bark usually direct their attack against trees previously weakened through drought, defoliation, fire, or some other cause. Most of the bark beetles are decidedly secondary and only attack trees already in a weakened or dying condition. A few species, however, are aggressive and primary in their attacks.

It is true that the destruction of older, mature trees in the forest through attack by insects is more or less of a natural process. It is nature's way of disposing of the old decadent trees to make room for the younger, thriftier, growing individuals. Although a natural one, this is a most wasteful process from the economic standpoint, since the old trees carry a large volume of high-grade lumber. The prevention of this type of damage, therefore, is an important phase of forest protection.

When more of our forests come under intensive management, and mature trees are utilized before they become decadent, much of the present loss in virgin forests will be avoided. Until such a time, the only alternative is the application of the direct-control methods discussed at the end of this section.

KEY TO RECOGNITION OF INSECT INJURY TO MATURE TREES

A. Foliage fed upon; partially or wholly stripped from trees; or turning yellow or red. Trees sickly or dying. No insects working on main trunk, branches, or roots ---------- defoliators, page 58.
B. Terminal shoots, laterals, or tips deformed or killed. Remainder of tree appearing healthy ---------- twig feeders, page 29.
C. Entire tree, or a large part, sickly, dying, or dead; foliage fading, turning yellow or red. Bark and phloem of main trunk or roots mined by insects and killed ---------- bark miners, page 95.

LEAF FEEDERS AND DEFOLIATORS

No part of a forest tree offers nourishment to such a host of insects as do the leaves. There are literally thousands of insect species that feed on them in one way or another. Some mine within the needles, some skeletonize the leaves, and others eat the entire leaf tissues or suck the juices. Trees can withstand a great deal of such feeding without being seriously affected, and some such insect work is going on more or less constantly. If the feeding is heavy, the growth of the tree is retarded. If a high percentage of the leaf surface is destroyed, death of the tree may result. The damage done to the forest by defoliators is difficult to estimate since a large part of it involves only a loss of increment and not the death of trees. On the other hand, when epidemics of defoliators occur, their ability to destroy timber, especially coniferous timber, over large areas in a short time places them at the top of the list of destructive forest insects.

Defoliation affects very vital functions in a tree's life processes. Without leaves a tree is unable to regulate its moisture content, to acquire its carbon supply from the air, or to throw off its waste gases. When these important functions of transpiration, assimilation, and respiration are greatly retarded the tree dies. Death does not take place at once but only after a lapse of time in which certain peculiar changes take place. Craighead (*25*) has shown that spruce budworm defoliation of fir and spruce not only results in a general reduction of growth but that this reduction is not evenly distributed (*82*). Growth is greatly retarded at the top of these trees, as shown

by the annual rings, while for the year of defoliation the ring at the base of the tree is enlarged over that of the previous year. Unable to throw off the excessive moisture brought up by the roots, the water and sap accumulate under the bark and ferment. Often this sets up an attractive influence that draws the bark beetles into the area, and trees are then killed which otherwise might have recovered.

The extent to which a tree may be injured by defoliation will depend upon the tree species, whether evergreen or deciduous, the position of the tree within the stand, its general health, the insect species involved, and the time of year when the defoliation occurs. Since evergreens cannot replace their leaves as readily as deciduous trees, they are much more seriously injured by defoliation than those that normally shed their leaves each year. One year of severe defoliation may be enough to kill such trees as Douglas fir, hemlock, and ponderosa pine. Alders and oaks, on the other hand, can sometimes withstand several seasons of defoliation without fatal injury. Dominant trees are more resistant than their suppressed neighbors, and vigorous trees have a better chance of resisting attacks than those weakened from one cause or another. Defoliators usually show little preference for weakened trees as do many of the bark beetles and are more apt to feed indiscriminately on whatever foliage of their favorite hosts happens to be at hand.

Outbreaks of defoliators are characteristically sporadic. For many years the forester may not observe a single specimen of some important leaf-feeding insect, and then without warning a sudden outbreak may occur and the forest is swarming with millions of caterpillars or slugs that devour everything in their path. Such outbreaks usually go through a 3- to 5-year cycle. First, there is a preepidemic stage in which the insect becomes unusually numerous. Then there is the epidemic stage, which usually lasts for 3 years, the first year showing evident damage, the second year a peak of damage, and the third year one of declining numbers but still with evident injury. Third, there is the post-epidemic period in which the insect returns to a normal or quiescent status. This decline in the epidemic is brought about by natural control factors such as an increase in parasitic enemies and disease or through some climatic condition which is unfavorable to a continued activity of the defoliators.

The aim in control is not to eradicate the insects but to protect the forest from heavy and concentrated feeding during the height of occasional epidemics. Although more expensive methods can always be used on individual trees of high value, such as ornamental, park, and shade trees, spraying and airplane dusting are the only methods now used to protect large timber stands during outbreaks of defoliating insects. These methods are discussed under the heading "Control of defoliating insects" (p. 175).

The leaf-eating insects include all of those leaf-feeding forms that have biting mouth parts and actually bite into and swallow their leafy food. They may be divided into three groups: (1) the leaf chewers, that feed externally upon and devour any part of the leaf, (2) the leaf skeletonizers, that eat out the green chlorophyll and leave only the network of veins and midribs, and (3) the leaf miners, that burrow through and feed between the surfaces of the leaves or needles.

Some leaf-feeding insects are skeletonizers in their early stages and then devour all of the leaf as they become more mature. Some mine the interior of the leaf when very young and then, later on, eat all of it.

Outbreaks of leaf chewers do not always result in the death of the defoliated trees. For instance, large forest areas in Washington, Canada, and Alaska have been badly defoliated by the hemlock budworm for 2 or more years in succession and yet most of the trees have recovered. On the other hand, outbreaks of the hemlock looper, the pine butterfly, and the Douglas fir tussock moth have resulted in the death of billions of feet of standing timber, with a high percentage of the stand killed over hundreds of thousands of acres.

While the work of leaf feeders is easily detected, considerable injury frequently occurs before their activities are noticed. Since young caterpillars are more easily killed by poison than older ones, early detection and control are important.

As these leaf chewers actually swallow and digest their leafy food, the method of artificial control is to spray or dust the foliage with a stomach poison, such as an insecticide containing arsenic. Where small trees that can be reached with dusting or spraying machinery are involved, the application of such a poison is a simple operation. Treating large forest areas is quite a different matter, and this usually can be done only by means of airplanes. Application of insecticides by this method is discussed in the section on forest insect control.

Insects comprising the group of leaf eaters are mostly either caterpillars (Lepidoptera) or sawflies (Hymenoptera), but a few beetles do similar work. No attempt will be made to list all the insects which under certain conditions may prove destructive, and in the following pages are mentioned only those that have proved particularly injurious and with which the forester should, if possible, become familiar.

KEY TO DIAGNOSIS OF INJURY FROM IMPORTANT DEFOLIATING INSECTS

A. Foliage appearing thin or sparse. Leaves chewed, mined, skeletonized, or stripped from the trees.

- 1. Leaves chewed, and defoliated part of tree covered with silken web. Work of caterpillars with three pairs of true legs and less than six pairs of prolegs.
    - *a.* Leaves and buds at tips of branches webbed together and fed upon by nearly hairless caterpillars, that wriggle violently backwards or fall to the ground when disturbed______ bud moths or budworms, page 78.
    - *b.* Large, dense, conspicuous, silken tents formed at end of branches or in crotches; made by very hairy caterpillars with blue, red, or yellow markings. tent caterpillars, page 72.
    - *c.* Loosely woven tents formed at ends of branches of broadleaved trees; made by yellowish-brown or gray caterpillars clothed with long white hairs, arising from black and orange tubercles. fall webworm, page 68.
    - *d.* Defoliated portion or entire tree covered with a very light fine cobweb of silken threads.
        - (1) Caterpillars nearly naked or with only fine hairs.
            - *aa.* Dark-green caterpillars with fine, closely set hairs and two lateral white stripes on each side. Feeding on pine_____ pine butterfly, page 62.

bb. Caterpillars travelling with a looping motion; with three pairs of true legs in front and two or three pairs of prolegs in the rear.
loopers or measuring worms, page 74.

cc. Olive-green caterpillars with black and yellow stripes on top and sides, brown or red heads; feeding on California oaks.
California oak worm, page 68.

(2) Caterpillars very hairy.

aa. Caterpillars brightly marked with blue, red, or yellow spots and long pencils or distinct tufts of hairs like a toothbrush.
tussock moths, page 69.

bb. Caterpillars of dull colors, black, and yellow, feeding in masses on terminal branches.
tiger moths, page 66.

cc. Blackish caterpillars with row of nearly square, white blotches along the back, irregular white marks along the sides, and brown spines and longer, paler hairs. Feeding on poplar and willow.
satin moth, page 72.

2. Leaves chewed, but defoliated part of tree not covered with silken webbing.

a. Work done by caterpillars with scattered spines or hairs; three pairs of front legs, four pairs of median prolegs, and one pair of anal larvapods.

(1) Yellowish-green or brown, leathery caterpillars with short dark hairs and seven or eight stout branched spines on nearly every segment; feeding on ponderosa pine.
pandora moth, page 64.

(2) Black caterpillars with fine, branched spines on each segment, middle row of spines bright yellow; feeding on species of Ceanothus.
California tortoise shell butterfly, page 165.

(3) Large, stout caterpillars with sparse, stout tubercles; feeding on broadleaved trees and shrubs------------------ giant silk moths.

(4) Yellow and black caterpillars with branched spines; feeding on willow, popular, and other broadleaved trees and shrubs
brown day moth.

b. Work done by naked slugs with three pairs of true legs and six to eight pairs of prolegs; sometimes covered with slime; one end of body frequently held in midair when disturbed------- sawflies, page 87.

3. Leaves mined internally.

a. Working inside of coniferous needles
needle miners, page 85.

b. Working in broad leaves-------------- leaf miners, page 86.

4. Leaves skeletonized, with midribs and veins still evident.

a. Work on broadleaved trees done by active grubs with three pairs of true legs, or by hard-shelled beetles [6]------------------------ leaf beetles, page 92.

B. Trees sickly, leaves not chewed but yellowing or covered with a sticky exudation or black smut------------------- sap-sucking insects, page 44.

C. Leaves stunted, galled, or swollen--------------------- gall makers, page 52.

[6] Similar work is done on broadleaved trees by a great variety of caterpillars, sawflies, etc., and to be certain of the insect responsible, specimens must be captured and identified.

MOST IMPORTANT PINE DEFOLIATORS

The pine butterfly (*Neophasia menapia* Feld.) (*31*) is potentially one of the most dangerous enemies of ponderosa pine in the Northwestern States. One of the earliest recorded outbreaks occurred near Spokane, Wash., in 1882. Since that date several outbreaks have developed in the ponderosa pine stands of Oregon, Washington, Idaho, and British Columbia. One of the worst of these occurred on the Yakima Indian Reservation in Washington during the period 1893–95. Ponderosa pine over approximately 150,000 acres was affected and from 20 to 90 percent of the stand killed over this large area. The total loss amounted to nearly a billion board feet, and the effects of this outbreak are still evident. A more recent outbreak severely defoliated thousands of acres of ponderosa pine along the Little Salmon and Payette Rivers in Idaho in 1922 and 1923. Old, mature ponderosa pines are more susceptible to injury than the younger, thriftier trees. Western white pine and lodgepole pine, when in mixture with ponderosa pine, are also attacked, and Douglas fir is reported to have been injured in outbreaks of the pine butterfly along the coast of British Columbia.

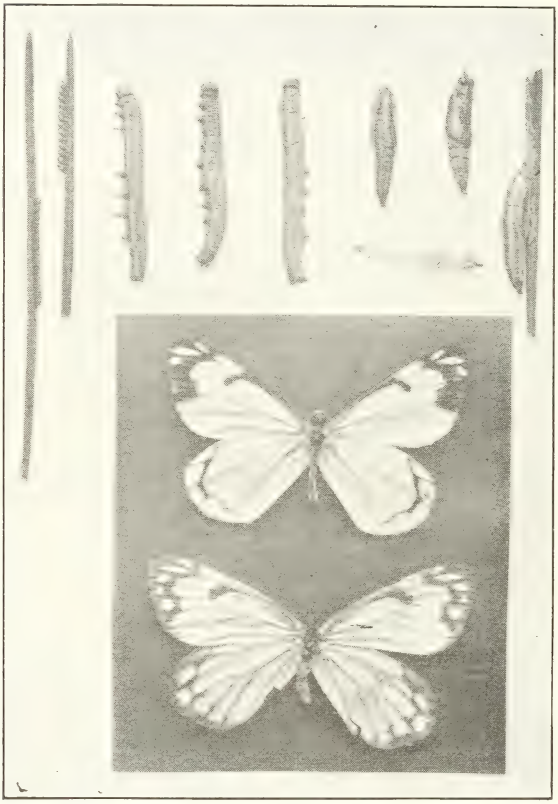

FIGURE 27.—The pine butterfly (*Neophasia menapia*): Eggs, larvae, pupae, and adults, male above, female below. Natural size. (Evenden.)

The adult (fig. 27) is a white butterfly with black markings and a wing expanse of about 1¾ inches, resembling in general the common cabbage butterfly. The wings of the male are pure white except for some black markings on the tips. The forewings of the female have similar black markings, but have a distinct yellowish cast; the hind wings have the same yellowish cast but have a much heavier black marking than in the male. With many females, but not all, there are bright orange spots along the apical margin of the hind wings. These butterflies may be seen nearly every year flying about in pine and fir forests and hovering about the tops of trees.

Flight of the butterflies occurs in August, September, and October, and emerald-green eggs are laid on the needles a few hours after mating. These eggs are attached to needles near the tops of the trees and are laid in rows at an angle of 45°, with from 5 to 20 eggs in each row, and are firmly cemented together (fig. 28). The winter is passed in the egg stage, and the eggs hatch the following June, or about the time the new needles begin to appear on ponderosa pine. The larvae, as they hatch from the eggs, are very small, pale-green caterpillars, with shiny black heads. The young larvae feed in clusters, encircling the needle with their heads pointed toward the tip, forming a little ring of tiny black heads. Later on they feed

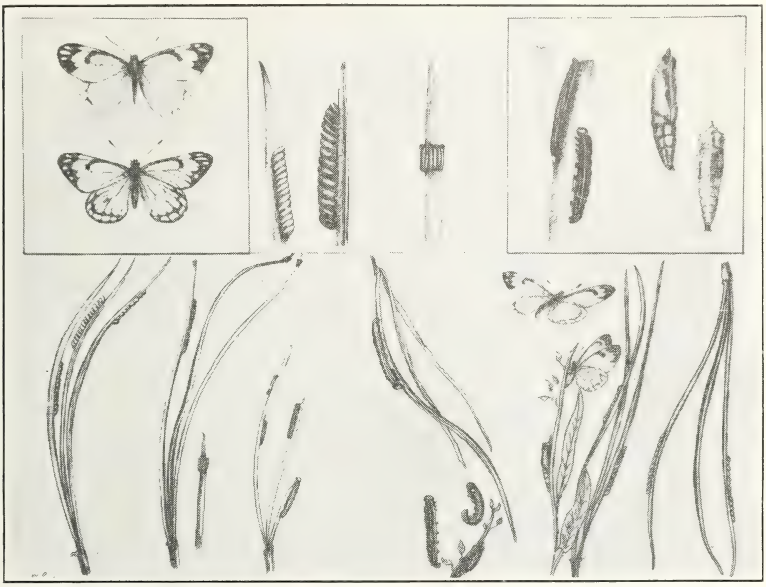

FIGURE 28.—Progressive stages of the pine butterfly. (Drawings by Edmonston.)

singly and reach maturity by the latter part of July. When mature they are approximately 1 inch long, dark green, and covered with fine, closely set hairs, and with two white lateral stripes down each side. The anal shield is produced behind into two blunt, well-separated projections. The head is pale green and covered with short hairs. The full-grown larvae lower themselves to the ground by silken threads and then ascend low-growing vegetation to transform to pupae, forming chrysalids attached to shrubs, grasses, limbs, and tree trunks. From 15 to 20 days are spent in the pupal stage, and then the insects emerge as mature butterflies. Normally there is one generation a year.

Outbreaks of the pine butterfly seldom last for more than 3 or 4 years, for nature has provided a wasplike parasite (*Theronia fulvescens* Cress.) which was apparently responsible for the reduction of past outbreaks of this destructive pest. In the recent outbreak in central Idaho, it was found that during the third year of the epidemic over 90 percent of the caterpillars were parasitized by this

beneficial insect, and during the following season it was practically impossible to find a living caterpillar or butterfly within the defoliated areas. Before natural control becomes effective, however, tremendous loss of timber may occur.

In the future, artificial control by airplane dusting may prove useful in protecting the forests from heavy defoliation during the peak of the outbreak and until the defoliator is brought under control by natural means. Even if only 50 percent of the foliage of a tree could be saved by such a method it probably would be sufficient to prevent its death.

The Pandora moth (*Coloradia pandora* Blake) (*68*) (fig. 29) is an important defoliator of ponderosa pine in the forests of central and southern Oregon and in California east of the Sierra Nevada. This moth and closely related species and varieties have been reported from practically all Western States, where they feed upon various pines. The preferred hosts of the pandora moth are ponderosa and Jeffrey pines, though lodgepole pine may also be attacked during epidemics when in mixture with one of the preferred species. Though distributed over a wide area, it is only in pine forests growing on loose pumice soil, where the caterpillars can easily bury themselves for pupation, that serious damage has occurred.

The most recent destructive outbreak occurred on the Klamath Indian Reservation of southern Oregon from 1918 to 1925. Thousands of acres of ponderosa pine forest were heavily defoliated, with an accompanying serious loss of timber. Heavily defoliated trees were unable to recover and died after 2 or 3 years as a direct result of the injury. Others were greatly reduced in growth and recovered only after a period of several years. The loss in growth throughout the defoliated area amounted to several million board feet. Even more serious was the bark-beetle damage which followed the defoliation and increased to alarming proportions in the weakened trees.

While some infestation may be found every few years, the records indicate that epidemics occur at fairly regular intervals of 20 to 30 years and continue in intensity for from 6 to 8 years. During periods of abundance fairly heavy feeding may occur without serious consequences. This is due to the fact that the terminal buds are not eaten, and since the insect has a 2-year life cycle and the larvae feed only in alternate years, the trees have an opportunity to recover. For this reason the more vigorous trees survive the attacks, and only during the major outbreaks are heavy losses likely to be sustained.

The adults are large, heavy-bodied, grayish-brown moths with a wing expanse of 3 or 4 inches, and a small dark spot near the center of each wing. The base and interior margins of the hind wings are clothed with pinkish hairs, which in the male shade to wine color. The males have large, feathery antennae, while the females have slender antennae and heavy bodies. During epidemics thousands of these large moths will be seen fluttering over the tree trunks and flying through the woods. The eggs, which are globular in shape and about one-tenth of an inch in length, are laid in clusters on the trunks or branches of trees or on litter on the ground. The

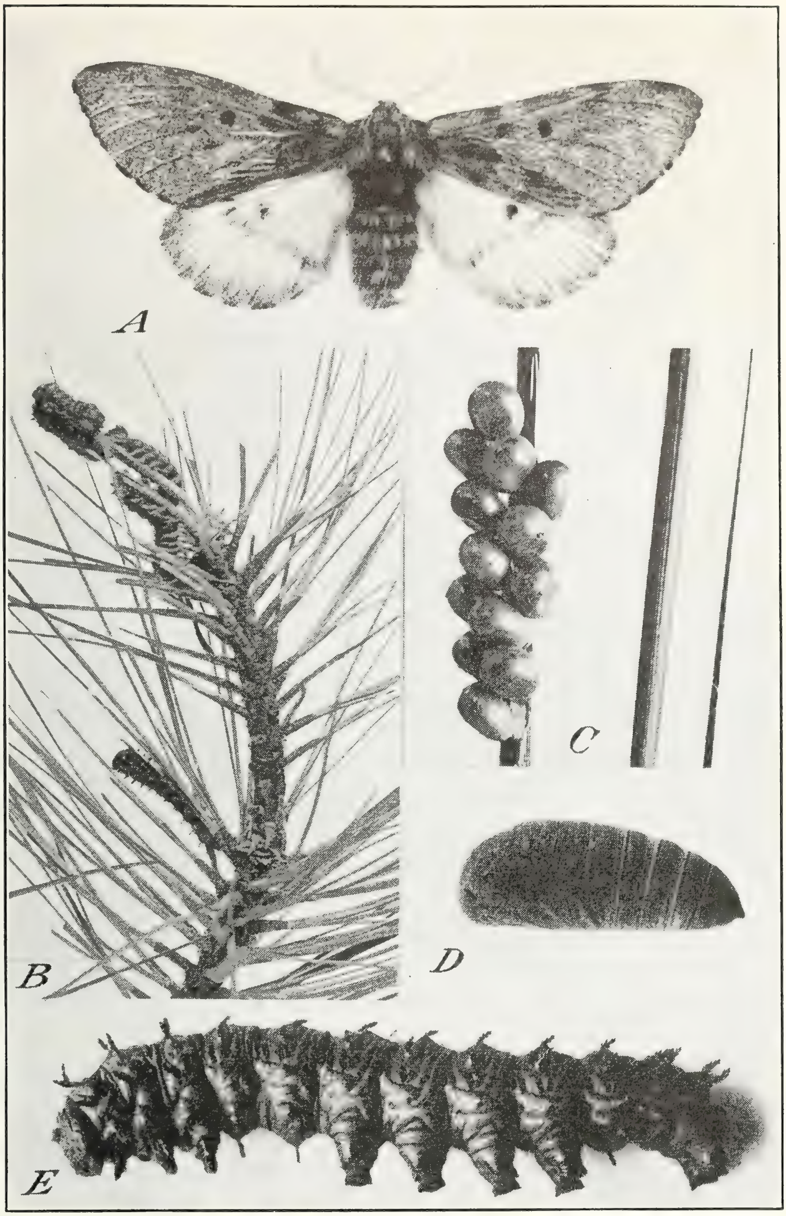

FIGURE 29.—The pandora moth (*Coloradia pandora*): *A*, Adult male, natural size; *B*, young larvae on pine needles; *C*, eggs, × 3; *D*, pupa; *E*, full-grown caterpillar, × 1.25.

newly hatched caterpillars are about one-fourth inch in length, with shiny black heads and black or brownish bodies covered with short, dark hairs. When mature, the caterpillars are from brown to yellowish green and 2½ to 3 inches in length, with each segment supporting a few stout branched spines.

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Two years are required for this insect to complete its life cycle. Adults appear during the latter part of June and in July, and the females deposit eggs that hatch in August. The young larvae crawl up the trees and during the early molts feed in groups on the new foliage. At the end of the season they are about 1 inch in length. The first winter is spent by these immature larvae hibernating in clusters at the base of the needles. Feeding is resumed in the following spring, and the caterpillars reach full growth by the last of June. When mature, they crawl down the trees and enter the soil to a depth of 1 to 5 inches, where they form elliptical cells, sometimes sparsely lined with a silky material, in which they transform to the pupal stage. The pupae are dark reddish brown and from 1 to 1½ inches in length and about one-half inch in width. The pupal stage lasts a full year, and the moths are not ready to emerge until the following June and July.

An interesting side light on the economic importance of this insect is that the larvae or pupae form a delectable food for certain Indian tribes. The Mono Indians of California dig trenches around the infested trees and build smudge fires which cause the caterpillars to drop to the ground in great numbers. They are caught in the trenches, killed, dried, and subsequently cooked with vegetables to make a stew. The Klamath Indians in Oregon prefer the pupae, which, when dug from the ground and roasted or boiled, are considered a great delicacy.

Epidemics of the pandora moth are brought under control by a number of natural enemies. Probably the most important is a wilt disease that attacks them at about the time they reach full growth and start to descend the trees. Once this disease becomes well established it runs rampant through the hordes of caterpillars, and very few of the insects escape. Ground squirrels and chipmunks dig up and destroy large quantities of pupae. Birds feed only sparingly on the caterpillars, which appear to be distasteful to most of them. Four or more species of insect parasites attack the caterpillars and dispose of a large number.

This defoliator could be held in check by spraying or dusting trees with arsenicals during the spring period of maximum feeding, provided such insecticides could be applied at a reasonable cost. Airplane dusting is about the only way in which such poisons could be applied to large forested areas, and because of the cost it is questionable to what extent such a method could be used.

Another method of control which was tried by a private timber company on a large tract of privately owned land in southern Oregon is light burning. In the fall of 1922, fire was run through this tract while the pandora caterpillars were feeding. The smoke and heat caused them to drop to the ground, where they were destroyed. On account of the damage and danger which may ensue in the use of fire, this method is of questionable benefit. The remedy may easily be "worse than the disease."

TIGER MOTHS

(Arctiidae)

The tiger moths are so named on account of the contrasting colors shown by many. Some of the species are without markings, but the majority are unusually beautiful. The caterpillars are robust

and very hairy, some of them being referred to as "woolly bears." Most of the family are important as leaf feeders.

The silver-spotted halisidota (*Halisidota argentata* Pack.) (fig. 30) is a strikingly colored yellowish-brown moth with a wing spread of about 2 inches and a body covered with long yellow hairs. The forewings are reddish brown with numerous uniform silvery-white spots. The hind wings have a few brown marks near the outer

FIGURE 30.—The silver-spotted halisidota; *A*, Full-grown caterpillar; *B*, eggs on needles; *C*, adult male; *D*, adult female. All natural size.

margin. The large moths emerge, fly, and mate during July and August. Pea-green eggs are deposited in clusters on the twigs and needles of the host trees. As many as 325 eggs have been laid by one moth. The caterpillars, which are densely clothed with long brownish to black hairs, congregate and feed heavily on the needles of young Douglas fir, balsam firs, pine, and spruce and are often

found in dense clusters on the twigs, where they hibernate during the winter. In June the mature caterpillars spin cocoons, which are composed of silk and larval body hairs, and attached to the needles or twigs of the defoliated trees. In these cocoons they pupate. The species is distributed from Colorado to California and Oregon. Control measures under forest conditions are not likely to be justifiable.

There are several closely related species of the genus which are also forest-tree leaf feeders. *Halisidota ingens* Hy. Edws. feeds on the needles of ponderosa and piñon pine in Colorado. *H. maculata* Harr. and its various varieties are found in all of the Western States, feeding on willow, oak, maple, alder, poplar, and a variety of other trees and shrubs. *H. sobrina* Stretch feeds on Monterey pine in California.

The fall webworm (*Hyphantria cunea* Drury) is a common defoliator of broadleaved trees, such as madroña, alder, willow, cottonwood, and various other shade trees, fruit trees, and ornamentals, but it is of little importance from a forestry standpoint. The caterpillars, when full grown, are pale yellow to brown but appear grayish because of the long whitish hairs that arise from black and orange tubercles. They spin very large webs, within which they feed upon the foliage. These tents often enclose an entire branch and are very conspicuous late in the summer. Feeding takes place from July 1 to September 15. Maturity is reached late in the fall, and the winter is passed as pupae in dark-brown cocoons on the ground or attached to the tree trunks. The following spring the adult moths appear. These are nearly white, with a few black spots on the wings and orange markings on body and legs. A spotless form is called *H. textor* Harris.

The California oak worm (*Phryganidia californica* Pack.) (*18*) (fig. 31) periodically defoliates the various species of oaks in California and sometimes attacks other trees in the vicinity of heavily infested oaks. It is particularly injurious to shade and ornamental oaks in the San Francisco Bay district, and not only renders the trees unsightly but may seriously weaken them or even cause their death.

The moths have a body about one-half inch in length, and wings of light brown with darker veins and a spread of about 1¼ inches. The males are distinguished by having yellowish patches near the center of the forehead and by their broader and more feathery antennae. Full-grown caterpillars are about 1 inch in length, and of a dark olive green with conspicuous black and yellow longitudinal stripes on the back and sides.

The females lay eggs in groups of 2 to 40 on the under sides of oak leaves, on tree trunks, or other convenient places. The young caterpillars skeletonize the leaves, and later, as they reach full growth, consume all of the leaf. Two generations are produced each year. The moths fly in June and again in November. The winter is passed in the egg and early larval stages.

Natural enemies include the spined soldier bug, a tachinid fly, and several species of wasplike parasites. A wilt disease takes a heavy toll of the caterpillars during epidemics. As a result of these natural control agencies, outbreaks occur only at irregular intervals.

The control of this defoliator can be accomplished by spraying in March and April with lead arsenate spray when the worms are very small and again during the last of July and first part of August.

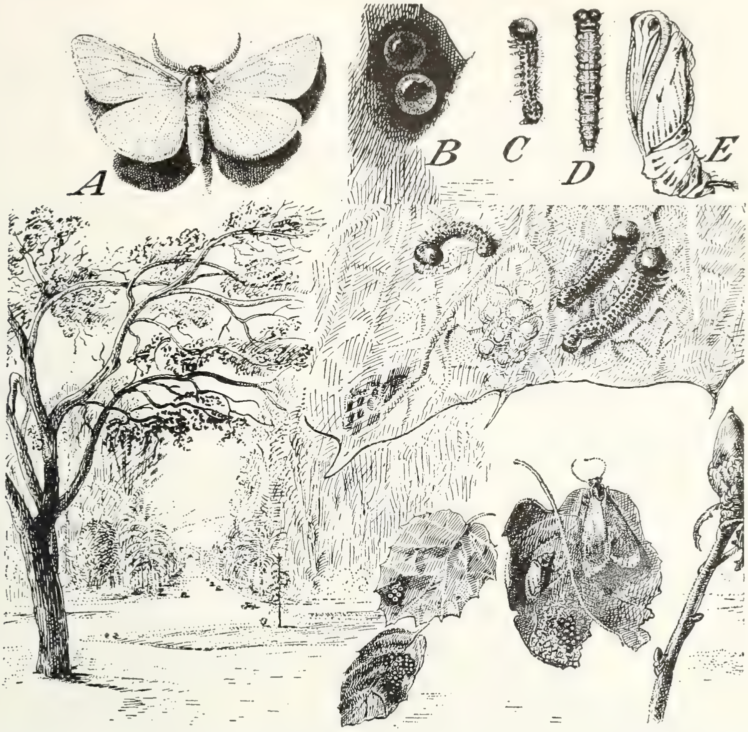

FIGURE 31.—The California oak worm (*Phryganidia californica*) : *A*, Adult moth, natural size ; *B*, eggs, × 4 ; *C*, young larva, × 3 ; *D*, full-grown larvae, × ¾ ; *E*, pupa, × 2. (Drawings by Edmonston.)

TUSSOCK MOTHS

(*Hemerocampa* spp.)

The tussock moths represent a very destructive group of leaf-feeding insects that attack coniferous species as well as broadleaved trees. The adults are dark-brown or dull colored, very fuzzy moths, that are chiefly nocturnal in habit. The males fly, but the wings of the females are but short pads, of no use for flight. The abdomens of the females are large and covered with a mat of dark-gray hair. The full-grown caterpillars are strikingly marked and very hairy with prominent pencils or small tufts of hairs on all the body segments, the whole giving much the appearance of a toothbrush. The larval hairs are easily detached and in some species are somewhat poisonous, causing a rash or eczema when they come in contact with the skin.

The female lays small white eggs in a mass on top of her own cocoon and covers them with a frothy, gelatinous secretion in which are embedded hairs from her body. The eggs hatch into tiny, very hairy caterpillars. Since the females are unable to fly, the principal time of dispersion is probably during this young caterpillar stage,

for the light, hairy caterpillars can be easily picked up and carried by air currents for long distances. When disturbed or when in search of food, the larger larvae lower themselves to the ground by silken threads and travel rapidly, but dispersion at this stage could only be for short distances at most. Pupation takes place within a gray cocoon made of silk mixed with larval hairs. These may be attached to the twigs, limbs, or trunks of trees or on the underbrush. These cocoons are sometimes formed in masses six or seven layers deep, and in such cases the moths from the lower ones are unable to emerge.

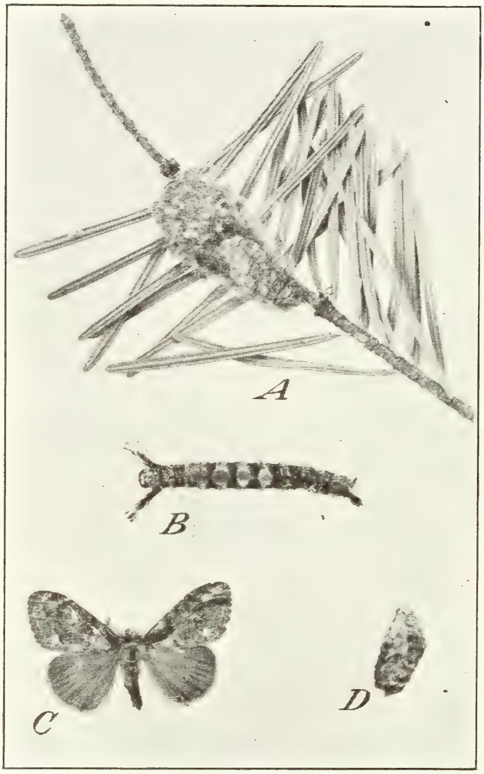

FIGURE 32.—The Douglas fir tussock moth (*Hemerocampa pseudotsugata*): *A*, Female laying eggs on cocoon; *B*, larva; *C*, male moth; *D*, female moth. Natural size.

The Douglas fir tussock moth (*Hemerocampa pseudotsugata* McD.) (*2*) (fig. 32) is a defoliator of major importance in the Douglas fir and balsam fir forests of eastern Oregon, Washington, and British Columbia, and in Nevada and Idaho. It was first discovered in British Columbia in 1918, where it was severely defoliating Douglas fir, and since then local damage has been noted at several points. The species was not recorded from the United States until 1927, when an outbreak occurred in Nevada. Then in 1929 several outbreaks were found in different sections of Idaho, northeastern Washington, and eastern Oregon. The epidemic in the Colville National Forest, Wash., reached a peak in 1930, spread over many square miles, and killed at least 300,000,000 board feet of Douglas fir and balsam fir. The Douglas fir which was not killed outright by the defoliation subsequently succumbed in many cases to the attacks of the Douglas fir beetle. These extensive killings have been followed by some disastrous fires.

The Douglas fir tussock moth shows a decided preference for Douglas fir and species of balsam fir and can increase to epidemic numbers only when feeding on these preferred host trees. It will, however, feed on other species of conifers when mixed with firs, and even on the underbrush. Defoliation first occurs at the tops of trees, and as this foliage is destroyed the caterpillars work down on the lower foliage.

The caterpillars of this tussock moth are striking looking creatures, decorated with brightly colored tufts of hairs. When full grown they are from three-fourths to 1 inch in length, with gray or light-brown bodies and black, shiny heads. There are two long brushes or pencils of black hairs fully one-fourth inch in length, suggesting horns, directly behind the head, and a similar but longer tuft at the posterior end of the body. On the upper side of the first four and the last abdominal segments are dense, light-brown or cream-colored tufts of hairs about one-sixteenth of an inch in length, and numerous red spots. Along the sides of the body are somewhat broken, narrow, orange stripes, while the lower side of the body is nearly naked, with the prolegs only sparsely covered with hairs.

The adult moths are far more ordinary looking than their handsome larvae, being a dull brownish gray. The males are about one-half inch long and have a wing expanse of nearly an inch. The wingless females are about one-half the length of the males.

Normally there appears to be one generation a year. The small caterpillars hatch from the eggs and commence feeding on the new foliage early in spring, but it is not until about the 1st of August that the defoliation is likely to become severe enough to be noticeable at a distance. The larvae reach full growth early in August and then pupate. The moths appear the latter part of August and mate soon after emergence. The winter is passed in the egg stage.

One of the most important parasites is a tachinid fly, somewhat larger and more hairy than the ordinary housefly. The larvae of this fly live in the caterpillars and emerge after these have formed their cocoons. A very small wasplike insect, *Trichogramma minutum* Riley, attacks the eggs and destroys a high percentage of them. There are at least five other wasplike insects that are important parasites of the larvae.

Determination of the feasibility of artificial control of this defoliator involves not only the consideration of effective methods but the cost of applying them. The spreading of arsenical dust by airplane probably would offer the best chance of success of any method, but at this time it cannot be recommended on account of risk and cost. Such methods as collecting and destroying the egg masses during the winter months, jarring the caterpillars from the trees, banding the trees to prevent ascent of the caterpillars, and power spraying, are applicable to the control of this insect only under park or shade-tree conditions.

Other closely related species of tussock moths which feed on forest trees in the Western States include:

Species	Host and distribution
Hemerocampa oslari Barnes	White fir. California and Colorado.
Hemerocampa vetusta Bdv	Oak, poplar, willow, and various other broadleaved trees. Pacific coast.
Hemerocampa gulosa Hy. Edw	Oak. California Sierras.
Hemerocampa leucostigma A.and S.	Poplar and other broadleaved trees. In the East, and west into Colorado and British Columbia.
Notolophus antiqua L	Alder, ash, aspen, larch, oak, pine, poplar, willow, and other broadleaved trees and shrubs. From California to British Columbia and east to Montana.

THE SATIN MOTH

The satin moth (*Stilpnotia salicis* L.) (*10*) is a very injurious leaf-eating enemy of poplars and willows. This moth, which is native to Europe, was first reported in 1920, both in New England and British Columbia. Since then the British Columbia introduction has spread throughout western Washington and into Oregon. It is a serious pest of planted shade and roadside trees, and may prove destructive to native poplars and willows.

The adults are large white moths with a satiny luster, a wing expanse of approximately 1¾ inches, black eyes and legs, and a tuft of hairs at the tip of the abdomen. The full-grown caterpillars are about 2 inches in length, black with white markings on the sides, a row of nearly square white marks along the back, and with brown spines and long hairs.

There is but one generation a year. During the flight of the moths in July eggs are laid on trees or other objects in oval patches covered with a white, satiny secretion which glistens in the sun. The young larvae feed for a short time and then spin small cocoons or hibernacula in bark crevices, where they pass the winter. Feeding is resumed in the spring, and the larvae reach maturity in June. Pupation occurs in loosely woven cocoons attached to leaves or other objects.

It was introduced without its European parasites, but it is attacked by several native enemies, including tachinid flies, parasitic wasps, sarcophagid beetles, mites, and birds. Some of these have proved very effective in holding it in check. From 1929 to 1934, five species of parasites of European origin were colonized and liberated in Washington. Four of these have become established and at least one, *Apanteles solitarius* Ratz., has become abundant enough to show apparent effect.

Direct control is obtained by spraying the trees in the spring with a stomach poison such as lead arsenate. When egg masses are exceptionally abundant they should be treated with creosote.

TENT CATERPILLARS

(*Malacosoma* spp.)

Tent caterpillars (*78*), which are responsible for the defoliation of many different species of trees and shrubs, can be recognized by the large compact webs at the terminals of branches, which are such a common sight during April and May. The various species are indigenous to this continent, being widely distributed over the United States. Outbreaks were recorded from Massachusetts as early as 1646. Coniferous trees are sometimes attacked, but the preferred hosts are deciduous trees and shrubs. While large forest areas are sometimes defoliated, the resultant damage is usually of no great importance, since deciduous trees can readily recover from the loss of foliage.

The caterpillars that construct the tents are usually yellow to brown, with rows of blue or orange spots and lines, and are lightly covered with long hairs. A heavy, silk-lined cocoon is usually formed in bark crevices or in leaves webbed together. The adults are tawny yellow or brown moths or millers and are frequently seen flying about lights at night.

There is usually but one generation of these insects a year. Adult moths appear in midsummer and deposit masses of eggs in bands encircling small twigs. The eggs do not hatch until the leaves appear the following spring. The young larvae feed on the new foliage, construct the large tents on terminal branches, and reach maturity early in the summer. They then form pupae, and the adult moths appear soon after.

Aside from the several species of predacious beetles and bugs that feed on the caterpillars, there are parasitic insects that lay their eggs within those of the moth, and the resulting minute larvae develop within the host eggs and destroy them. Further control is accomplished by parasitic insects that breed within the caterpillars and the pupae. Birds also play an active part in controlling the tent caterpillar nuisance, many species feeding upon the caterpillars, others feeding on the eggs, and still others, although to a lesser degree, on the moths. Often the most complete control is accomplished by a wilt disease that rapidly spreads among the colonies of caterpillars and leaves but few survivors.

There are six common species of tent caterpillars in the West, and they are most easily distinguished in the field by the markings on the caterpillars.

The forest tent caterpillar (*Malacosoma disstria* Hbn.) is dusky brown with a row of diamond or keyhole-shaped white spots along the back and sides and with fine brown hairs. It feeds in large colonies, without forming tents, on alder, birch, poplars, willows, and a large number of broadleaved trees. They are distributed generally over the United States.

The eastern tent caterpillar (*Malacosoma americana* F.) has a white line on the back, bordered with reddish brown, and on the sides a row of blue spots and reddish-brown and yellow lines. It feeds on various fruit, shade, and forest trees in the Eastern States and is found in the Rocky Mountain region from New Mexico to British Columbia.

The California tent caterpillar (*Malacosoma californica* Pack.) is orange red to brown above and paler brown below, with a blue line on each side. This species is found in California, where it feeds on ash, madroña, oak, willow, and other forest, shade, and fruit trees.

The blue-sided tent caterpillar (*Malacosoma constricta* Stretch) has an orange-brown body, with distinctly blue sides and blue dots along each side of the center. It feeds on oak and other trees in Arizona, California, and Oregon.

The Great Basin tent caterpillar (*Malacosoma fragilis* Stretch) (fig. 33) is distributed in the Great Basin region between the Rocky Mountains and the Cascade-Sierra Nevada ranges, where it feeds on bitterbrush, aspen, oak, poplar, willow, and other shrubs and trees. The caterpillars of this species are distinguished by having a pale-blue head and brown to black body, with a broad, pale-blue stripe down the middle, fine orange lines on each side of the center, and two blue spots on the sides of each segment. The hairs are whitish.

The western tent caterpillar (*Malacosoma pluvialis* Dyar) (fig. 34) is the common coastal species in the Pacific Northwest, that has as its favorite food the alder, though feeding on other forest and fruit trees.

The caterpillar is brown, with a row of elliptical blue spots down the center and two orange spots on each segment. On the sides are pale orange lines and spots.

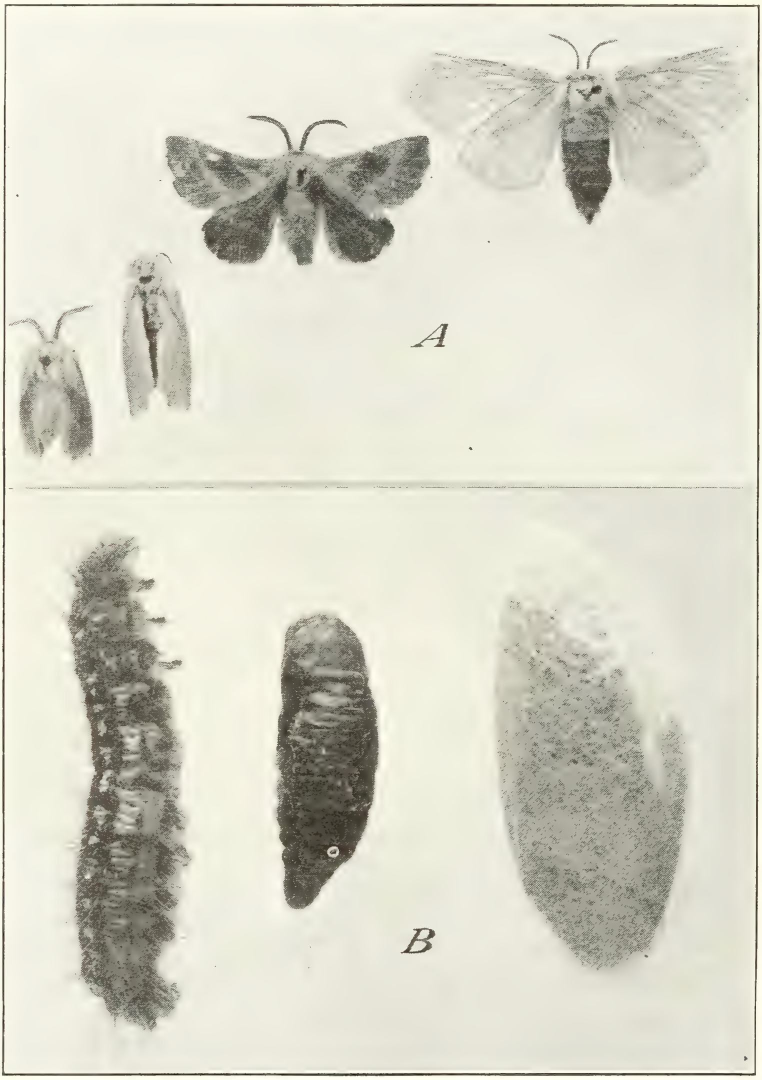

FIGURE 33.—Great Basin tent caterpillar (*Malacosoma fragilis*): *A*, Adults, natural size; *B*, larva, pupa, and cocoon, × 2.

LOOPERS, SPANWORMS, OR MEASURING WORMS

(Geometridae)

The leaf-feeding caterpillars of this family of moths infest a great many species and varieties of trees and plants. Some species are among the most destructive defoliators of forest trees. The cater-

pillars are smooth, nearly hairless, with three pairs of true legs in front and two or three pair of prolegs on the rear of the abdomen. These species can easily be recognized by the characteristic way in which the caterpillars travel. They move along by grasping with the hind pairs of prolegs while they extend the body forward, then holding with the front legs while they hump their backs to bring up their rear. This produces a looping motion, from which arises the common names of loopers, spanworms, inchworms, or measuring worms. Adults are medium-sized, slight-bodied, and light-colored moths of which the hemlock or oak looper is a typical example.

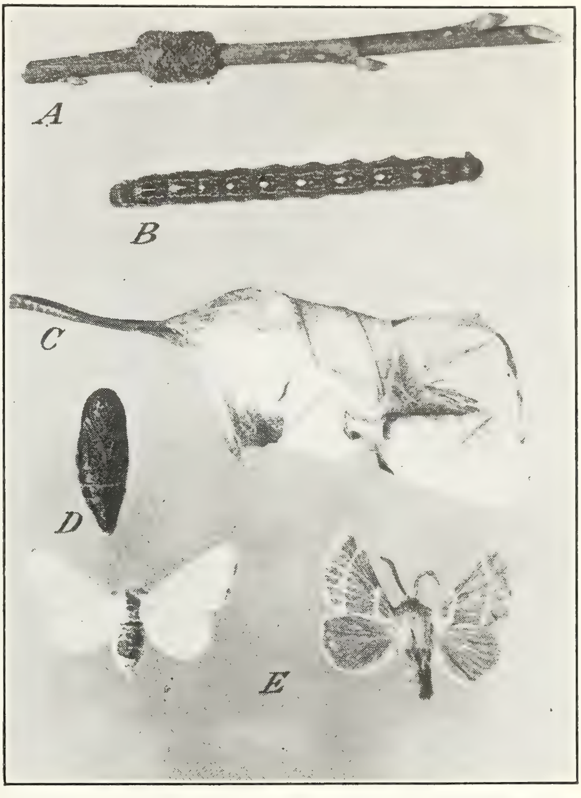

FIGURE 34.—The western tent caterpillar (*Malacosoma pluvialis*): *A*, Egg mass on alder branch; *B*, full-grown caterpillar; *C*, cocoon webbed in curled leaf; *D*, pupa; *E*, adult moths. All natural size.

The hemlock looper (*Ellopia fiscellaria* Guen.) (*85*) (*49b*) is a very destructive defoliator in the spruce, hemlock, and balsam fir forests of the Northeastern States, through Canada, the Lake States, and along the northwestern coast. At intervals it appears in great numbers, strips the needles from trees over large areas and causes their death. These defoliated trees become very dry, and jungles of fallen trees and broken tops soon follow that are frequently swept by disastrous fires.

The species that destroys the spruce-hemlock forests along the coast of Oregon, Washington, and British Columbia has been referred to as the variety *lugubrosa* Hulst (fig. 35). During the last 40 years it has figured in three major outbreaks. The earliest outbreak of record occurred about 1889 to 1891, when a vast amount of timber in Tillamook and Clatsop Counties, Oreg., and Grays Harbor County, Wash., was destroyed. The second outbreak occurred again in Tillamook County in 1918–21, when several townships were affected and 500,000,000 board feet of hemlock and Douglas fir were reported to have been killed. The latest outbreak occurred in Pacific and Grays Harbor Counties, Wash., from 1929

to 1932, when 50,000 acres were involved and about 200,000,000 feet of hemlock timber destroyed.

Although western hemlock is the preferred host, the caterpillars appear in countless thousands when an outbreak occurs and feed on any foliage at hand. Douglas fir, Sitka spruce, and western red cedar may be heavily attacked when in mixture with hemlock; also huckleberry, salal, and broadleaved forest shrubs and trees are frequently eaten. In fact, when the caterpillars are exceptionally numerous, nothing green is left on the infested areas.

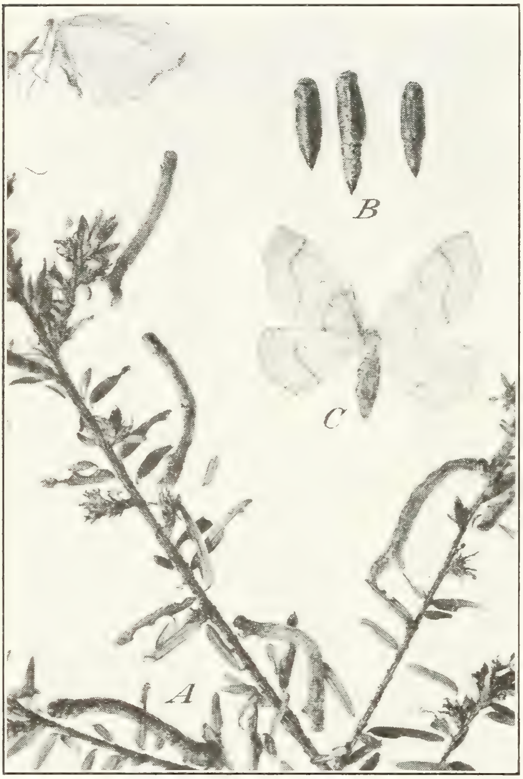

FIGURE 35.—The hemlock looper (*Ellopia fiscellaria* var. *lugubrosa*): *A*, Larvae on branch; *B*, pupae; *C*, adult moth. Natural size.

The moths are light buff, with a wing expanse of about 1½ inches. The forewings are marked with two wavy lines and the hind wings with one wavy line. They fly, mate, and lay eggs late in September and during October. The eggs are about the size of a pinhead, gray green or brown, and are attached to the moss on the tree trunks, or to twigs or branches. It is in this stage that the winter is passed, and the eggs hatch the following spring. The young larvae, which are about one-fourth inch in length, crawl up the tree trunks and start feeding on the young needles. The first feeding takes place in May, June, and the early part of July and is not particularly noticeable. However, from the middle of July to October the feeding of the caterpillars causes a heavily infested forest to turn yellowish red and then brown, as though scorched by fire. Late in summer the caterpillars feed on the foliage, clip off small twigs, crawl over the trunks, cling to shrubs, and drop by silken webs from the trees to the ground. These silken webs may become so abundant that the whole forest looks and feels like one big cobweb. When full grown, the caterpillars are about 1½ inches long, green to brown, with diamond-shaped markings on the back. They drop to the ground in August and September and secrete themselves in protected places, such as crevices of the bark or under debris on the ground, and there transform to pupae.

The pupae are mottled, greenish brown, about one-half inch long, and are unprotected by a cocoon. The moths appear within 10 to 14 days and during an epidemic are so abundant as to give the impression of a snowstorm in the woods. Creeks, springs, and rivers are covered with the dead bodies, and tree trunks are plastered with them until heavy rains wash them into the ground or carry them away. There is one generation annually.

Outbreaks usually last for about 3 years, after which they are generally brought under control by the action of parasites, predators, and disease. Heavy rains during the flight period reduce egg laying, checking an epidemic and hastening its decline.

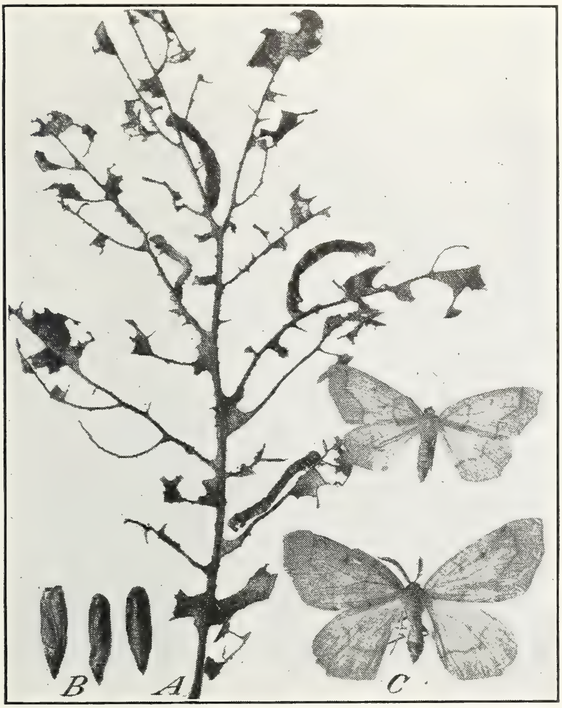

FIGURE 36.—The oak looper (*Ellopia somniaria*): *A*, Caterpillars on defoliated branch; *B*, pupae; *C*, adult moths, female above, male below. Natural size.

Although nature will ultimately bring outbreaks under control, a vast amount of timber might be saved if artificial control measures could be applied to protect the trees from heavy defoliation. It has been found that trees can recover from a 50-percent defoliation, and in some cases a 75-percent defoliation is not fatal unless the trees are subsequently attacked by bark beetles. At present, airplane dusting (*33*, *54*) offers the only practical means of controlling this defoliator on large forest areas, but because of high risk and cost, it can be applied only under particularly favorable circumstances. (See discussion on p. 178.)

The oak looper (*Ellopia somniaria* Hulst) (fig. 36) is so closely related to the hemlock looper that some entomologists consider the distinction questionable. At least this probably represents a variety or race of loopers that shows a distinct preference for Oregon white (Garry's) oak, on which it feeds in Oregon and northward into British Columbia. Other trees may be attacked but usually only when intermingled with the preferred host tree. In some seasons the oaks in Willamette Valley in Oregon are completely defoliated over large areas by this species. No permanent damage is done, however, since the oaks are able to leaf out again the following year.

The New Mexico fir looper (*Galenara consimilis* Hein.) (fig. 37) has periodically destroyed timber over considerable areas in the spruce-fir type at the higher elevations of the southern Rocky Mountain region, particularly in New Mexico. Douglas fir seems to be the preferred host, but balsam fir and spruce foliage is also eaten.

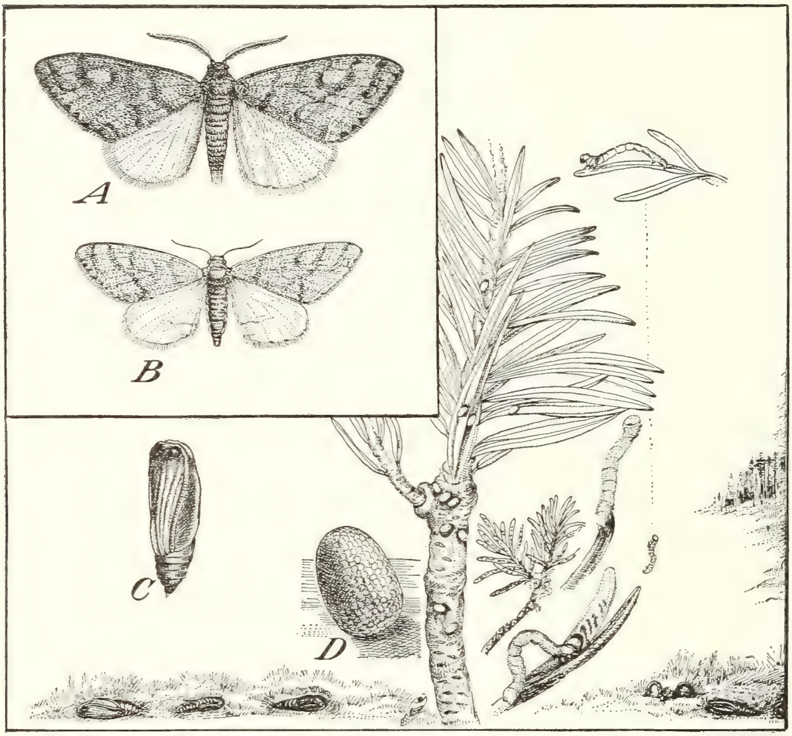

FIGURE 37.—The New Mexico fir looper (*Galenara consimilis*): *A*, Male moth, × 1.3; *B*, female moth, × 1.3; *C*, pupa, × 1.6; *D*, egg, greatly enlarged. (Drawings by Edmonston.)

BUD MOTHS, BUDWORMS, AND LEAF ROLLERS

One group of moths, belonging largely to the family Tortricidae, lay their eggs on the needles of coniferous trees or the leaves of various broadleaved trees, and the young caterpillars feed on the opening buds and new leaves or needles, drawing these together with a silken web. Later, as they become larger, they may leave their protective web and feed openly on the leaves or older needles and if numerous will completely defoliate the tree. When growth is completed the larvae transform to the pupal stage, usually in small webs spun about the dead foliage at the tips of the branches, and from these the full-grown moths emerge.

Under normal conditions the damage consists only of a few dead tips or partly eaten leaves. When buds are killed, subsequent branching results at these points, but seldom is the life of the tree threatened. When epidemic outbreaks occur, large forest areas may be completely defoliated and killed.

The spruce budworm, (*Harmologa*) *Cacoecia fumiferana* Clem. (*25*, *82*) (fig. 38), is one of the most destructive members of this group. In the Northeast, in Canada, the Lake States, and the northern Rocky Mountain region it has caused widespread destruction of spruce, balsam firs, and Douglas fir. There are many records of budworm epidemics in the Northeast in which enormous numbers of spruces and balsams have been destroyed. It was not until 1922, however, when two outbreaks were recorded in widely separated sections of

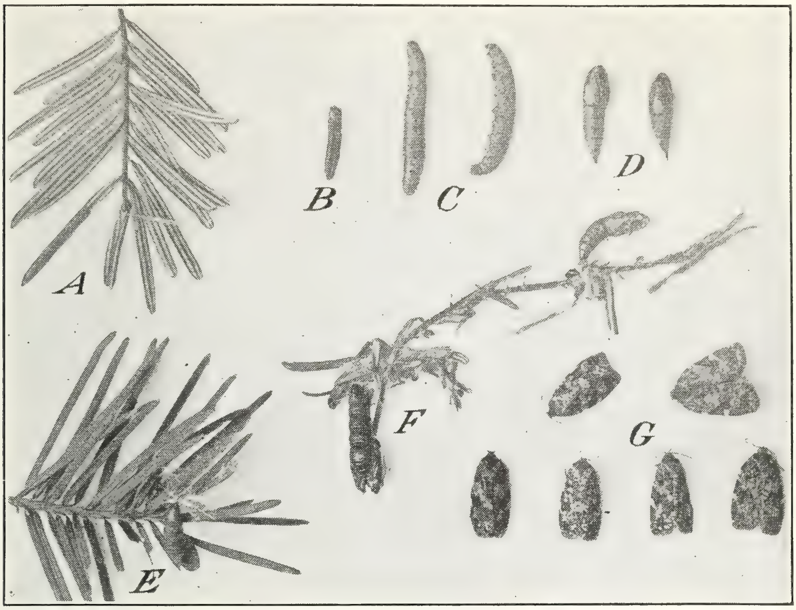

FIGURE 38.—The spruce budworm (*Cacoecia fumiferana*): *A*, Eggs on under side of fir needle; *B*, half-grown caterpillar; *C*, full-grown caterpillars; *D*, pupae; *E*, fir twig with pupa attached; *F*, defoliated fir twig with empty pupal cases; *G*, adult moths. All natural size. (Evenden.)

Idaho, that it was recognized as an important enemy in western forests. The following season it was found that a budworm epidemic had been present for several years in the southwestern corner of Yellowstone National Park and the adjacent Targhee National Forest, and in the next few seasons outbreaks were reported from many Western States. In some areas these outbreaks reached alarming proportions and heavy timber losses followed. Though it is not known whether this insect migrated or spread to the western part of the United States from infested areas in the East, it is believed that it is indigenous to the West and that during the last 30 or 40 years it has been at such a low endemic stage as to escape attention.

The adult spruce budworms are small, mottled, brownish moths with a wing expanse of approximately 1 inch, with no distinctive markings, the general color tone being a dull gray. The oval, scale-like eggs, which are light green and about one-sixteenth of an inch in diameter, are laid on the under side of needles, in an overlapping form like shingles, with about one-third of the egg exposed. The

mature larvae are approximately 1 inch in length, deep brown, with yellowish, pale-green markings and numerous small, wartlike growths along the sides.

The moths can be seen hovering around infested trees late in July or early in August. The females lay their eggs on the needles of the upper branches of fir and spruce trees, where the tops are in the sunlight. A female lays approximately 150 eggs in masses of about 12, and these hatch during the latter part of July. After hatching, the young larvae wander about for a few days in search of a suitable place to spin their cocoons and in these they hibernate. It is not definitely known whether the young larvae feed before hibernation, but if they do, it is very sparingly. The following spring they emerge from their winter nests simultaneously with the opening of the new buds, which they immediately attack, entering them either directly through the base or between the opening scales, and hollowing them out. As the new tender needle growth develops this is fed upon. Later on the larvae bind together the needles at the tips of the branches loosely with silk, bite them off at the base, and form a shelter of dead needles, bud scales, and frass. When disturbed, the larvae hide in these retreats, or drop from the limbs and hang by silken threads, which are used to return to the nests if no further disturbance occurs. After 3 or 4 weeks of feeding, about the last of July, the larvae reach maturity and construct loose cocoons of silk and dead needles, in which they pupate. The moths emerge in from 10 to 12 days. Thus there is one generation annually.

When attacks are heavy entire trees are stripped of foliage and killed and large areas of forest take on a brownish, scorched appearance (fig. 39). When defoliation is not so complete the trees show a blighted or scorched appearance at the tips of limbs where the new foliage has been destroyed. Even moderate feeding tends to reduce growth, weaken the trees, and render them susceptible to later destruction by secondary insect enemies.

In the western part of the United States the balsam firs and Douglas fir appear to be preferred hosts of the spruce budworm, and the greatest damage has occurred in pure stands of these two species. The budworm has also been found attacking Engelmann spruce, western larch, western hemlock, western white pine, ponderosa pine, and lodgepole pine. Budworm attacks on pines are usually limited to individual trees occurring in association with the preferred hosts, though serious outbreaks in pure lodgepole pine have occurred in and adjacent to the southwestern corner of Yellowstone National Park. In all cases the new foliage is destroyed first, old needles being attacked only when the preferred supply is exhausted. Larvae will often migrate from one tree to another in search of new foliage rather than feed on old needles.

As in the case of most defoliators, the spruce budworm is preyed upon by numerous insect parasites and predators and by disease, and these in normal years tend to keep the pest under control. The natural enemies and a shortage of food usually are responsible for eventually subduing an outbreak.

The control of spruce budworm epidemics by artificial methods is not ordinarily practical because of the difficulties and expense

involved. As the caterpillars feed within the buds, or within clusters of needles, they are difficult to reach with stomach poisons. Outbreaks usually cover thousands of acres of rough, mountainous country, and it is rarely possible to apply poisons with any type of ground machine. Airplane dusting has been used in eastern Canada with fair success. Along roadways and in parks the budworm can be controlled by the application of arsenical sprays with the aid of power pumps just after the buds open in the spring. Such control work has recently been done in the Shoshone National Forest, Wyo., with fair results.

FIGURE 39.—A forest after defoliation by the spruce budworm.

The black-headed budworm (*Peronea variana* Fern.) is an important defoliator in balsam fir, hemlock, and spruce forests in the northern part of the United States, Canada (*3*), and Alaska. In the Northeast and in eastern Canada it has appeared in destructive numbers only where mature balsam fir forms a high percentage of the stand.

In the Pacific Northwest hemlock appears to be the preferred host, although Douglas fir, balsam fir, spruce, and larch are also attacked. In this region one or two outbreaks have been recorded in which thousands of acres of western hemlock have been severely defoliated. Fortunately, however, this has resulted in killing very little merchantable timber. Frequently the black-headed budworm occurs in outbreaks with the hemlock looper and assists in the destruction wrought by this insect.

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The small moths, that are gray or dappled with brown, black, orange, and white, and have a wing expanse of three-fourths of an inch, appear during August and September, mate, and lay their eggs on the under side of the needles. The eggs remain unhatched during the winter, but in the spring the small, pale caterpillars appear and start feeding on the new foliage of opening buds. They work in much the same way as the spruce budworm, boring into and feeding on the opening buds and webbing the new needles together to form a protective case within which they feed. As they develop they become bright green, and the head turns black. If disturbed they actively wiggle backwards and drop to the ground by silken threads. They reach full growth by the last of July, at which time they are a trifle more than a half-inch in length and may have brown heads.

Usually they confine their work to the new growth, but if they are numerous the larger caterpillars will leave the nests and feed upon the older needles, bringing about complete defoliation. Pupation takes place within a web made among the dead needles and frass on the twigs. Prior to emergence, the pupa, which is dark reddish brown with a greenish tint, works partly out of the web so as to allow the moth freedom to emerge. There is but one generation a year.

A small amount of feeding by the black-headed budworm takes place every year, but it is scarcely noticeable. When an attack is heavy toward the end of July, the forest takes on a reddish-brown appearance. This is due to the dying of the new foliage that is partly eaten but remains attached to the twigs by the webs of the caterpillars. Their presence can be confirmed by finding the small, wiggly, green caterpillars, or the brown pupae, among the webs at the tips of the branches. For some reason heavy defoliation by this insect does not prove so disastrous to the trees as similar work by other species, such as the hemlock looper. Even repeated heavy defoliations of western hemlock for 2 or more years have not caused any serious loss of timber.

The larvae of the black-headed budworm are parasitized by numerous insects and are affected by a wilt disease. These agencies become dominant and bring outbreaks under control within 2 or 3 years.

The sugar pine tortrix, (*Tortrix*) *Cacoecia lambertianae* Busck (fig. 40), is at times very destructive to the new buds and pollen bodies of sugar pine, killing as much as 90 percent of the new growth on the trees. The caterpillars feed in colonies within a web on the terminal shoots and transform to adults in July. The adults are speckled tan to golden moths with a wing expanse of about seven-eighths of an inch.

The lodgepole pine needle tier or pine tube moth, (*Eulia*) *Argyrotaenia pinatubana* Kearf., (*16*) (fig. 41) is found in the Rocky Mountain region, where it works on lodgepole pine. Usually it is not particularly destructive, but from 1921 to 1925, working in conjunction with the lodgepole sawfly (*Neodiprion burkei* Midd.), it destroyed trees over a large area of immature lodgepole pine near West Yellowstone, in Montana. Since the cessation of the sawfly epidemic the needle tier is still present in many areas, but has ceased to be destructive.

The adult needle tier is a small brownish-gray moth with darker patches and bands on the forewings and a wing expanse of about one-half inch. Eggs are laid during the latter part of June and early in July in groups of 2 to 30, with an average of about 10 per cluster, on the concave side of lodgepole pine needles. These eggs hatch in 7 to 10 days, and the young larvae crawl over the foliage until needles satisfactory for their attack are found—usually those of the current year's growth. Each larva then enters a needle by

FIGURE 40.—The sugar pine tortrix (*Cacoecia lambertianae*) and its damage to sugar pine terminals.

biting a circular hole near the tip and spends from 2 to 3 weeks in feeding on the interior tissues. The inside of the mined needle is lined with a papery, white, closely woven web to form a tube. At an early period in the growth of the larva or when it becomes too large for the mined needle, several other needles are drawn to it and bound together so as to form a new and larger tube (fig. 41, *B*). This tube is also lined with a papery white web and has an opening at each end, that allows the insect to leave quickly when disturbed. Often a caterpillar will abandon one tube and form a new one. Feeding takes place within the tube, and as the caterpillar becomes larger the tube is extended farther down the needles, often to the base.

During the latter part of August the mature caterpillar, which is dark green and about one-half inch in length, drops to the ground on a silken thread and, after crawling into the mat of old needles, spins a loosely woven cocoon in which the winter is passed in the pupal stage. The adult emerges the following May or June, completing one single annual generation. The work of the lodgepole pine needle tier is recognized by the silk-lined tubes, that may consist of as many as 16 needles webbed together, and which, as a result of the feeding, turn brown and die.

FIGURE 41.—The lodgepole pine needle tier (*Argyrotaenia pinatubana*): *A*, Webbed foliage; *B*, a silk-lined needle tube; *C*, full-grown larvae, × 2.

A related species, *Argyrotaenia citrana* Fern., feeds on the needles of Monterey pine in California.

The spruce budmoth (*Zeiraphera ratzeburgiana* Ratz.) is an introduced pest that has become established in the Pacific Northwest. The small, light-brown moths, with darker diagonal markings, and a wing expanse of about one-half inch, lay their eggs on spruce needles. Each young caterpillar crawls into an opening bud and feeds on the tender new needles, webbing them together to form a shelter within which it feeds. Growth is completed late in the summer, and the chrysalid is formed in the shelter at the tip of the infested twig. The adults emerge late in the summer. There appears to be one generation a year. The damage has been frequently noted on young Sitka spruce trees along the coast of Oregon and Washington. In many cases all of the new tips are killed and the tree made to branch excessively.

There are a large number of other budmoths and leaf rollers that infest the buds and young, tender leaves of various broadleaved trees and shrubs. This damage is often of a serious nature in orchards but seldom is of any importance in the forest. No attempt can be made to discuss these interesting but relatively unimportant species.

NEEDLE MINERS

Some leaf-eating insects have the habit of feeding internally on coniferous needles and thus protecting themselves within a thin, leafy covering. These are called needle miners. A great many of them cause only an insignificant amount of damage, but a few, such as the lodgepole needle miner, may defoliate extensive areas and contribute to the destruction of the timber cover on entire watersheds, as has happened in parts of the Yosemite National Park. The needle miners belong mostly to one small genus of moths.

Outbreaks of needle miners are eventually brought under control by the action of native parasites and the influence of climatic conditions. Direct control through the use of the ordinary sprays or dusts offers little hope of being effective since the insects work within their protective covering and would not be reached by these poisons. Recent experiments indicate that light, penetrating oil sprays to which nicotine has been added offer promise of being effective.

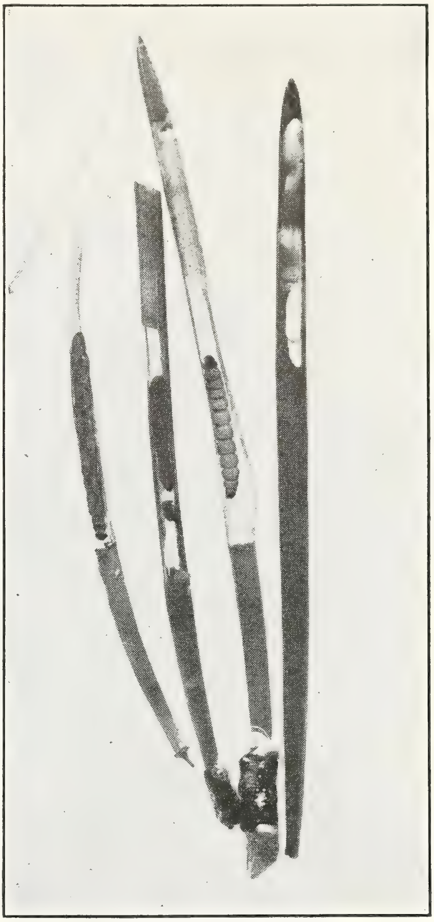

FIGURE 42.—The lodgepole needle miner (*Recurvaria milleri*), × 2.25.

The lodgepole needle miner (*Recurvaria milleri* Busck) (*66*) (fig. 42) is the best representative of this group in the West. As its name implies, it mines the needles of lodgepole pine and is found through the lodgepole pine forests of the Sierra Nevada in California. It has defoliated extensive areas of lodgepole pine in the Yosemite National Park and so weakened the trees that they readily succumbed to the attacks of the mountain pine beetle. The adults are very small white or grayish moths only about one-half inch long. The caterpillars are very small greenish worms with black heads. In the Yosemite National Park this species has a 2-year life cycle, the moths flying in alternate years.

Other very similar species of *Recurvaria* attack lodgepole pine in Oregon and Montana. These differ from the foregoing in having one generation annually. Extensive areas in the Deschutes National Forest have recently been seriously defoliated.

Another species, *Recurvaria moreonella* Hein., attacks ponderosa pine needles in southern Oregon on the Klamath Indian Reservation and occasionally causes heavy loss of foliage.

The spruce needle miner (*Taniva albolineana* Kearf.) bores into and mines the needles of Engelmann spruce near the base, webbing them together to form a mat of dead needles held to the twigs by the webs. Sometimes three or four larvae mine a single needle. They do considerable damage at times in Colorado.

LEAF MINERS

The leaves of many broadleaved trees are attacked by the larvae of many leaf-eating insects that bore within and feed internally on the leaf tissue. The damage they do is usually insignificant, since these trees are able to replace their foliage each year. Insects with the leaf-mining habit belong in the main to the order of the moths and butterflies (Lepidoptera), but a few beetles (Coleoptera), flies (Diptera), and wasps (Hymenoptera) also have this habit.

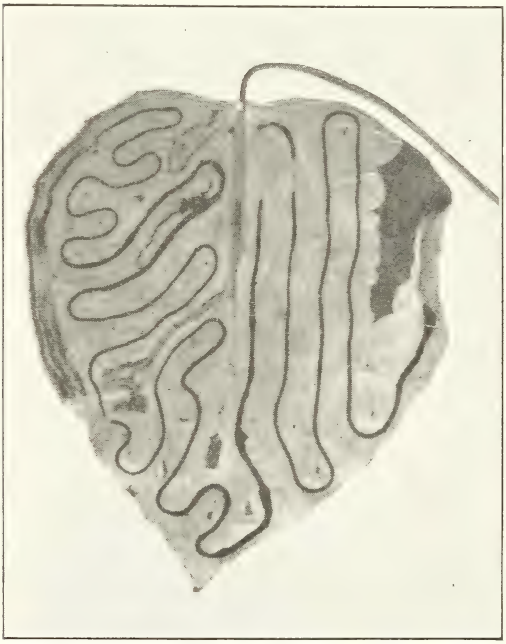

FIGURE 43.—Work of an aspen leaf miner (*Phyllocnistis populiella*).

The leaf blotch miners hollow out irregular-shaped mines or blotches between the upper and lower surfaces of leaves. There are many species that work on the leaves of various western broadleaved trees.

The madroña shield bearer (*Coptodisca arbutiella* Busck) mines the leaves of madroña and cuts out elliptical holes when constructing the pupal cases. Commonly associated with it in leaves of madroña is another leaf-mining species, *Marmara arbutiella* Busck.

The poplar leaf blotch miner (*Phyllonorycter tremuloidella* Braun) attacks the leaves of aspen and poplars and constructs irregularly shaped mines between the upper and lower leaf surfaces. It has been reported from California, Idaho, and British Columbia and no doubt has a more extended range. When mature, the larvae change to small black pupae within the mines and then emerge as

small, drab-colored moths. During heavy infestations practically all of the leaves on the lower portions of the trees are attacked, but infestation seldom extends above 50 feet. The damage results in a premature shedding of the foliage. Other species of *Phyllonorycter* include *P. salicifoliella* Chamb., which works in the under side of the leaves of willow, poplar, and cottonwood; *P. apicinigrella* Braun, which works in the under side of willow leaves; *P. felinella* Hein., which works in the under side of sycamore leaves in California; *P. incanella* Wlsm., which works in both sides of alder leaves; and *P. arbutusella* Braun, which works in the leaves of madroña.

Cameraria agrifoliella Braun works in the upper surface of leaves of coast live oak. *C. alnicolella* Wlsm. works in the upper surface of alder leaves. *C. umbellulariae* Wlsm. makes blister blotches on leaves of California laurel.

The aspen leaf miner *Phyllocnistis populiella* Chamb. (fig. 43) leaves a labyrinthian trail of frass as characteristic of its work in the under side of aspen and poplar leaves.

Common leaf miners in live oak include *Bucculatrix albertiella* Busck and *Abebaea subsylvella* Wlsm.

SAWFLIES

Sawflies form another important group of leaf-eating insects that in many cases cause extensive defoliation and destruction of timber. In the Northern States and in Canada, such species as the larch sawfly, the European spruce sawfly, and the jack pine sawfly have been responsible for the death of as much as 85 percent of the stand over thousands of acres. In the West the native sawflies occasionally develop widespread outbreaks and may cause heavy defoliation over limited areas, but the total timber destruction so far has not been great.

The sawflies (fig. 44) belong to the order of wasps (Hymenoptera) but in appearance are usually more like flies than wasps. They have thick, cylindrical bodies with four membranous wings, the hind pair somewhat smaller than the forewings. The head, thorax, and base of the abdomen are nearly equal in width. They range in size and color from small grayish insects not over one-fourth inch in length to large, showy species (*Cimbex*) over 1 inch long. They are called sawflies because of a sawlike attachment which the female carries at the tip of the abdomen and uses to slit open leaves or stems for the reception of her eggs. Usually only one egg is deposited in each slit, but as many as 14 or more punctures may be made in a single pine needle.

The larvae resemble hairless caterpillars except that most of them have from six to eight pairs of abdominal legs, or larvapods, on the abdominal segments, in addition to the usual three pairs of true legs on the thoracic segments. Because of their resemblance to caterpillars the larvae are sometimes called "false caterpillars"; and since many are wormlike and often slimy, they are called "slugs" or "worms." Most of them are typical external leaf chewers, but a few are leaf miners and even gall makers.

One of the most characteristic features distinguishing sawflies are the cylindrical, papery, capsulelike cocoons which the larvae fre-

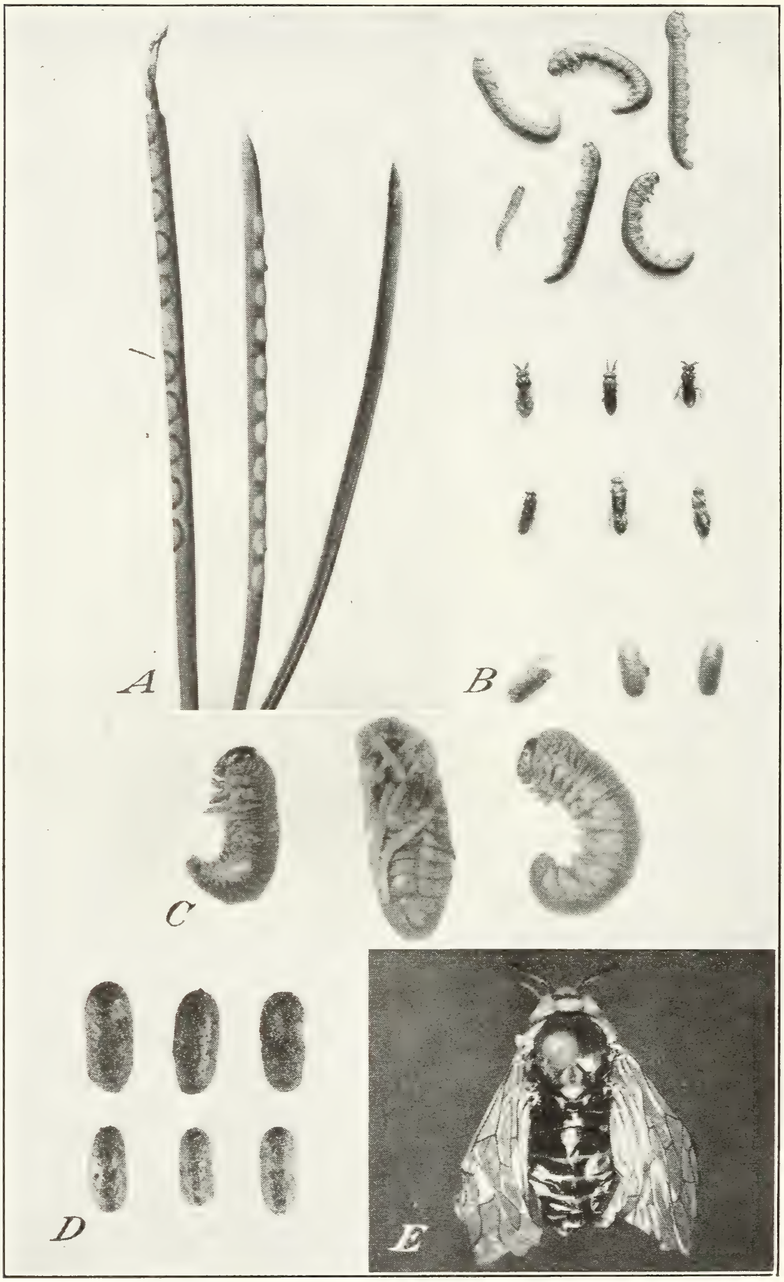

FIGURE 44.—Pine sawflies: *A*, Eggs on pine needles, × 2; *B*, larvae, adults, and cocoons of a pine sawfly, natural size; *C*, grubs and pupa, × 3.5; *D*, cocoons, × 1.5; *E*; adult of the lodgepole sawfly (*Neodiprion burkei*), × 4.

quently construct for their pupation. These are often formed on the debris of the forest floor, but may be attached to the needles or branches of the tree.

Sawflies, for the most part, complete their life cycle with one generation a year. With many species the winter is passed in the prepupal stage within the cocoon. In the spring the transformation to adult takes place. The adults emerge, mate, and deposit eggs in the new needles, leaves, or shoots. In some species part of the brood does not emerge from the cocoons until the second spring. The eggs hatch in about a week, and feeding starts on the foliage. Feeding is completed by the middle of summer, and the slugs drop to the ground to prepare for transformation, usually spinning the tough papery cocoons. Other species pass the winter in the eggs which hatch early in the spring, the larvae completing their feeding and transformation by fall, at which time flight and egg laying again take place.

The native sawflies are attacked by numerous parasites that play an important part in holding them in check, but weather conditions seem to be even more important in determining the number of sawflies in different seasons.

Direct control can be effected where it is practical to apply arsenical poisons, such as on shade and ornamental trees, or to forest areas by means of airplanes. Usually, however, the cost of control is not justified, because of expense, the difficulty of application of dusts, and the fact that most outbreaks are rather quickly suppressed by natural control agencies.

In the forests of western North America there are numerous native species of sawflies, which, although usually inconspicuous in numbers, may periodically become prevalent enough to cause noticeable damage. So far, although extensive defoliations have occurred, the actual destruction of timber has been small, and the outbreaks have quickly subsided.

Sawflies on Conifers

A number of species of sawflies belonging to several genera attack the needles of pines and other conifers. The adults are colored variously, often black or brown, and with yellowish appendages. They are usually from one-fourth to one-half inch in length. The males frequently have large, feathery antennae while those of the females are threadlike. Eggs are laid singly, in slits made in the needles.

The young hairless larvae first feed in clusters on the nearest needles, then as they grow they scatter out over the foliage and feed singly. Upon reaching full growth, about the first of September, they are from one-half to 1 inch in length, usually greenish, with black or brown heads, and have eight pairs of prolegs. Upon completing their feeding they usually drop to the ground and form brown, papery cocoons in the forest debris, but some may form cocoons on the needles or in crevices of the bark, while still others do not construct cocoons. The winter is usually passed in the prepupal, larval, or egg stage, and the new adults emerge the following spring. These sawflies are easily controlled where trees can be sprayed with lead arsenate or other stomach poisons.

The lodgepole sawfly (*Neodiprion burkei* Midd.) (fig. 45), in the adult stage, is about one-third of an inch long. The males are black and the females brownish. The hairless, wrinkled bodies of the larvae are greenish or grayish, with lighter lateral and dorsal stripes, brown heads, and black eyes, and are about 1 inch long when mature. This species developed a severe outbreak in 1921 over a large area of lodgepole pine at West Yellowstone, Mont. In the next few years a tremendous acreage of lodgepole pine was defoliated and a large percentage of the trees died. This outbreak was further complicated by a contemporary outbreak of the lodgepole pine needle tier (see p. 82). Control of both species along highways was effected by spraying with lead arsenate.

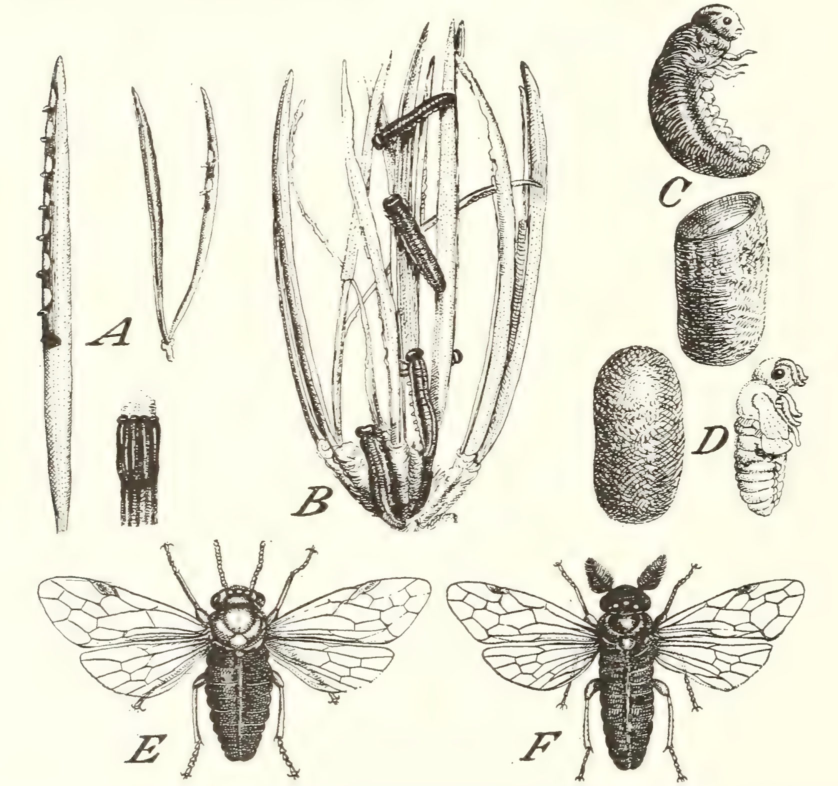

FIGURE 45.—Lodgepole sawfly (*Neodiprion burkei*): *A*, Egg pockets in needle and very young caterpillars feeding, × 1.5; *B*, larvae at work, natural size; *C*, hibernating prepupa, × 5; *D*, pupa, × 5; *E*, adult female, × 7; *F*, adult male, × 7.

Other species of the genus *Neodiprion* which feed on the needles of western pines include the following:

Species of *Neodiprion*	Host and distribution
N. fulviceps Cress	Ponderosa pine. California.
N. gillettei McGill	Ponderosa pine. Colorado.
N. edwardsii Norton	Sugar pine, western white pine. California.
N. rohweri Midd	Piñon and singleleaf pine. New Mexico and California.

The Monterey pine sawfly (*Itycorsia* sp.) attacks only the Monterey pine in its native habitat, near Pacific Grove, Calif. The larvae are so prevalent at times as to completely defoliate the trees, either killing or seriously weakening large numbers of them. The larvae are dark green or brownish, with black heads. A characteristic of their work is that the needles are sawed off or chewed into a mass, and these broken needles and brownish excrement pellets are webbed together with silken threads.

The hemlock sawfly (*Neodiprion tsugae* Midd.) occasionally becomes epidemic and defoliates extensive areas of western hemlock in Oregon and northward into Alaska. The adults are small, about one-fourth inch in length. The males are dark brown to black, and the females are larger and green to yellowish brown. The larvae are green and about 1 inch in length when full grown. The papery cocoons are attached to the needles and to debris on the ground.

In the northwestern part of the United States there are two species of sawflies that feed on the foliage of western larch. So far they have not caused damage of any great economic importance. In 1921 an outbreak of these two insects occurred throughout the larch stands of northern Idaho and western Montana. This is the first and last record of their appearance, and although they occurred in countless numbers in 1921, it was practically impossible to find a single larva in 1922. This is a marked example of how rapidly an outbreak can disappear.

The larvae did their heaviest feeding from the middle of July to the last of August, and either devoured the foliage or killed it by chewing on the fleshy portion of the needles anywhere between the tip and base. The larvae leave the trees when they are mature and spin small silken cocoons under the duff, in which they pupate. Small pebbles and grains of sand adhere to these cocoons, giving them the appearance of small lumps of dirt. The winter is passed in the cocoon, and the new adults emerge the following spring about the time the larch foliage appears.

Adults of the two-lined larch sawfly (*Platycampus laricis* Roh. and Midd.) are small, black, wasplike insects, a little less than one-fourth inch in length. The folded wings have a blue-green metallic sheen. The larvae are rather slender, about three-eighths inch in length when full grown, with eight pairs of prolegs on the abdomen and are brownish-green with two narrow dark-green stripes along the sides, dark-brown heads, and black, shiny eyes. The western larch sawfly (*Platycampus laricivorus* Roh. and Midd.) closely resembles the foregoing in the adult stage, but the larvae have a single green line down the center of the back.

The larch sawfly (*Nematus* (*Lygaeonematus*) *erichsonii* Hartig) which is a native of Europe and was first found in New England about 1880, has spread westward through the Lake States and Canada into northern British Columbia. Its progress has been disastrous inasmuch as it kills trees rapidly, and has left vast areas of dead and dying larch in its wake. Only recently it has been reported attacking western larch in southern British Columbia and in the northwestern part of the United States.

The cypress sawfly (*Susana cupressi* Roh. and Midd.) feeds on the foliage of Monterey cypress in California.

Sawflies on Broadleaved Trees

There are a large number of sawflies that feed on the leaves of broadleaved trees. Some of these produce galls, and many others feed externally on the leaves and cause a varying amount of damage. Only a few will be mentioned here.

The elm sawfly (*Cimbex americana* Leach) is commonly found in the Middle West as well as in the Eastern States, but ranges west into Colorado and British Columbia. These sawflies are active feeders on the leaves of willow and elm, and also attack poplar, alder, maple, and other trees. The adults are large, steel blue to black, broad-waisted sawflies about three-fourths of an inch in length with three or four yellow, oval spots on each side of the body, short knobbed antennae, and smoky wings. They girdle the bark on twigs and kill many of them, especially in the tops of trees. The larvae are naked, wrinkled, and pale yellowish with a median black stripe down the back, and have eight pairs of prolegs. They usually lie coiled and are from 1 to 2 inches long when full grown. The adults fly in May and insert their oval eggs in the leaves. The larvae reach full growth in July or August, and overwinter in cocoons in the debris on the ground or just below the surface. Pupation occurs in the spring, only a few days before emergence and flight.

At least three other sawflies attack willow in the West. *Cimbex pacifica* Cress., which has similar habits to the preceding, is found in Oregon and Washington, where the larvae feed on willow leaves. The adults are large, about 1 inch in length, and are brownish red. It is known as the Pacific sawfly. *Cimbex rubida* Cress. is found in the sierras of California and Nevada and along the coast, feeding on various species of willow. The adults are about three-fourths of an inch in length, reddish brown, with black stripes on the abdomen and wings of metallic blue or smoky brown. Another species, *Trichiosoma lanuginosa* Norton, also feeds on willow in the California and Nevada sierras. The adults, which are velvety or shiny bluish black, with dense pale-yellow hairs on head, thorax, and base of abdomen, look very much like large bumblebees. They are about three-eighths of an inch in length and have short knobbed antennae and smoky brown wings.

The cottonwood sawfly (*Pteronidea* sp.) although common, has not been identified specifically as yet. The larvae, which are slender, about one-half inch in length, green, with brown head and black eyes, and six pairs of prolegs on the abdomen, feed on the leaves of black cottonwood in northern Idaho. During the early feeding period the larvae skeletonize the leaves, eating only the fleshy part, but in the later stages of larval development the entire leaf is consumed. When mature the larvae construct small, parchmentlike cocoons that are attached to the leaves. The complete seasonal history of this insect has not been determined, but it appears to have one generation a year.

LEAF BEETLES

There are a number of beetles that are leaf eaters in the larval or adult stage or in both. None of these have been responsible for any noticeable injury to western coniferous forest trees, but the skeletonizing and defoliation of broadleaved trees by beetles is a

common occurrence. Most of these beetles belong to the family Chrysomelidae. The adults of this large family of destructive beetles are small, rather short, somewhat oval in outline, and of variegated colors, some with bright metallic green or blue and others dull brown or black. The larvae are rather stout, humpbacked grubs. Some are armed with spines, while others partially cover themselves with excrement. In western forests the alder flea beetle is probably the most common representative of this family.

No control appears practical or warranted under forest conditions, but on park and shade trees leaf beetles can be controlled by spraying with powdered acid lead arsenate at the rate of 4 pounds to 100 gallons of water. The spray should be applied as soon as the leaves unfold in the spring.

The alder flea beetle (*Altica bimarginata* Say) (fig. 46) is a native species found throughout the Pacific Coast States, where it feeds on and skeletonizes the foliage of alder, poplar, and willow, both as larvae and as adults. The adults are small, dark shiny blue, and about one-fourth inch long. The mature larvae are a trifle over one-fourth inch in length, dull brown to black, with shining black head and thorax and three pairs of short legs. The adults hibernate during the winter in debris beneath the trees and other sheltered places, appearing early in the spring to resume feeding. Clusters of yellow eggs are deposited sometime after the spring appearance of the adults. The larvae, which appear a few days later, reach maturity in August, and pupation occurs on the ground in the duff. New adults appear in a week or 10 days and feed voraciously on the foliage until the close of the season, when they hibernate for the winter, to appear the following spring, completing the cycle of one generation a year.

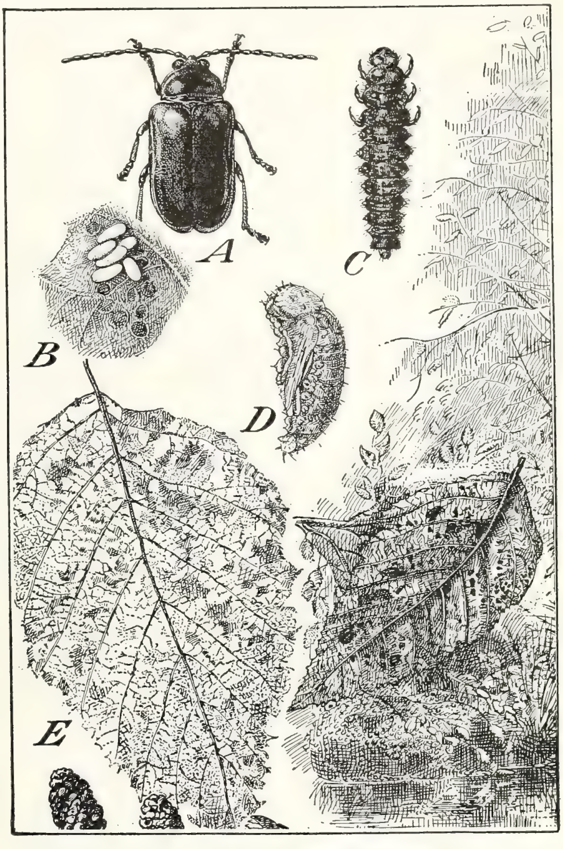

FIGURE 46.—Alder flea beetle (*Altica bimarginata*): *A*, Adult beetle, × 4; *B*, eggs, × 4; *C*, larva, × 4; *D*, pupa, × 4; *E*, skeletonized leaf.

The elm leaf beetle (*Galerucella xanthomelaena* Schrank) (=*G. luteola* Mull.) is an introduced pest which has proved to be very destructive to elms. Since 1834 it has gradually extended its range to include nearly all parts of the country where elms are grown. Trees are weakened and subject to attack by various boring insects or are killed outright by repeated defoliations. The adults are one-fourth inch in length and dull olive green with a black stripe on each elytron. The larvae are blackish yellow and about one-half inch long when full grown. Park and shade trees can be protected by spraying with arsenicals soon after the new leaves open in the spring.

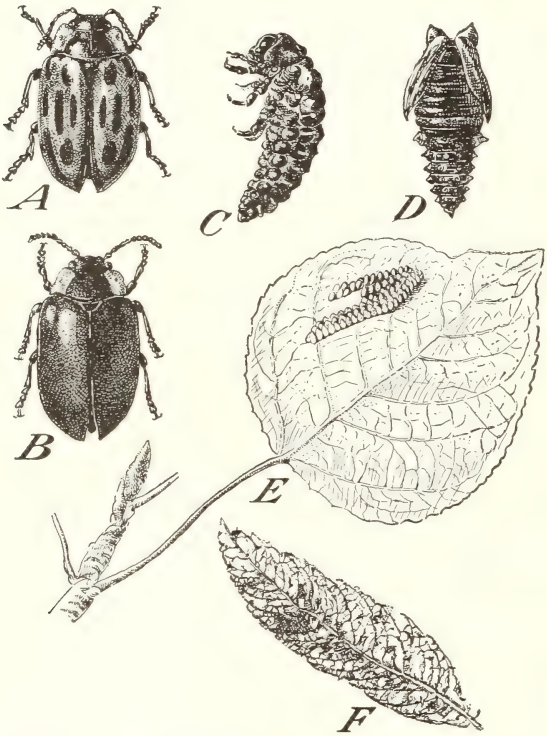

FIGURE 47.—Cottonwood leaf beetle (*Chrysomela scripta*): *A*, Female beetle, × 5; *B*, male beetle, × 5; *C*, larva, × 5; *D*, pupa, × 5; *E*, eggs on cottonwood leaf; *F*, skeletonized willow leaf.

The western willow leaf beetle (*Galerucella decora* Say) is a dull, yellow-brown to black native species that feeds on the leaves of willow and poplar throughout the country.

The cottonwood leaf beetle, (*Lina*) *Chrysomela scripta* F. (fig. 47), is found throughout the country, feeding on the leaves of willow and poplar. In New York it is very destructive to willows raised for basket-work, and often heavily defoliates these trees in the West. The adults are yellowish marked with black spots and are about one-fourth inch in length. They appear early in the spring and feed on the tender shoots. The eggs are yellowish or reddish and are deposited in clusters on the under surface of the leaves, and it is here that the black grubs feed as soon as hatched. The period of growth to the mature larval stage is about 15 days in hot weather. Five generations a year are reported in the West. *C. tremulae* F. feeds on aspen and poplars in the Pacific Northwest.

The willow leaf beetle (*Chrysomela interrupta* F.) is similar to the above, but smaller. It feeds on willow and ranges from California to Alaska. Another species, *C. californica* Rogers, is black to bluish green and feeds on willow in California.

The spotted willow leaf beetle (*Chrysomela lapponica* L.) is sometimes as prevalent and just as injurious to willows and poplars in the

Northwest as the cottonwood leaf beetle, which it closely resembles in appearance and habits. The adults are reddish, one-fourth inch in length, and spotted with black.

MINERS IN THE INNER BARK AND PHLOEM

Many different species and families of insects are represented among those that select the cambium region of the main trunk of trees as a suitable place to feed. All of these are chewing insects that bore under the bark and feed in the soft layers of bark and wood. As feeding progresses the channels may penetrate deeply into the sapwood or be extended into the outer bark.

The insects of this habit that are capable of attacking living, healthy trees are among the most destructive species with which the forester must deal. By far the greatest number of the cambium feeders, however, are capable of attacking only unhealthy, weakened, dying, or felled trees and cannot resist the copious flow of sap or resin which in the normal tree serves as a defense against attacking bark borers. At times, when a tree's resistance is low, even these normally secondary species may kill trees, if they attack in sufficient numbers.

It is easy to recognize the work of bark-feeding insects. Usually a close inspection of the trunk of an infested tree will reveal boring dust in the crevices of the bark or pitch exuding from small holes in the bark. These may or may not indicate bark-mining insects. Positive evidence of infestation can be obtained only by removing a small chip of bark and determining whether the phloem is fresh and white or discolored with the mines of some boring insects. If such mines are found, a larger piece of bark can be removed, and the species responsible for the damage usually can be identified by the character of its work.

A few species of inner-bark miners, such as the pitch moths, may work in the phloem from the edge of wounds without threatening the life of the tree, and no attempt need be made to control such species under forest conditions. Nor is it necessary to attempt any control of the vast number of inner-bark-feeding insects that confine their attack to weakened, sickly, or felled trees. Only those species that are capable of attacking and killing living trees need cause any concern, and fortunately the number of such species is very limited. It is not difficult for the forester to learn to recognize the comparatively few phloem-mining insects that are aggressive killers of the trees in his region. Such species are discussed in detail in the following pages.

KEY TO THE DIAGNOSIS OF INSECT INJURY TO THE INNER BARK

A. Entire tree or a large part sickly, dying, or dead; foliage fading, turning yellow or red. Inner bark of main trunk and sometimes roots attacked and killed.

1. Outside of bark showing boring dust collected in crevices, or small pitch tubes. Small egg tunnels under bark usually of uniform width, from which extend diverging tunnels usually packed with fine borings. The egg tunnels are made by small beetles while the diverging mines are made by small, white, curled, legless larvae------ bark beetles, page 96.

2. Bark showing no outward sign of insect attack. Tunnels under bark and sometimes entering wood; these increase in size with the growth of the white, often legless grubs which make them.
   a. Mines flattened, oval in cross section, usually packed with arc-like layers of boring dust made by slender grubs shaped like horseshoe nails; first thoracic segment greatly enlarged and flattened, with a horny plate on both top and bottom flatheaded borers, page 132.
   b. Mines broadly oval in cross section, made by elongate grubs which are thick in front with tapering bodies, thoracic segments enlarged, with horny plate on top only________ roundheaded borers, page 134.
   c. Mines round in cross section ending in pupal cells partly in the wood, often lined with shredded wood fibers. Usually at base, root collar, or roots of weakened trees. Sometimes in terminals and twigs__________________________ bark weevils, page 138.

B. Tree apparently healthy or in some cases top-killed. Large masses of pitch exuding from wounds on trunk or with the bark, on a dying top, appearing pitchy and dry, and separating from the wood as though scorched. Slender caterpillars with three pairs of legs found working in the pitch_______________ pitch moths, page 139.

BARK BEETLES

The common term "bark beetle" (*79*) is applied to a group of small beetles belonging to the family Scolytidae. They are the most destructive group of insects to be found associated with western coniferous forests. Recent estimates place the annual loss of timber in the Western States as a result of their activities at 2 billion board feet. The bulk of this destruction is caused by three species of *Dendroctonus*, the western pine beetle, the mountain pine beetle, and the Black Hills beetle.

The bark-beetle adults are small, cylindrical insects, ranging in size from the tiny *Crypturgus*, about one-twentieth of an inch in length, to the larger species of the genus *Dendroctonus*, that attain a length of approximately three-eighths of an inch. Most species are unicolored, dark brown, reddish brown, or black, and are either shining or dull, though a few species have variegated markings. The head, which is more or less hidden by the thorax, has chewing mouth parts, with well developed mandibles.

The adults of cambium-mining bark beetles have the very distinctive habit of boring through the bark and making a tunnel between bark and wood in which to lay their eggs. The complete work or engraving of the bark beetles is therefore characterized by having two types of tunnels—egg galleries, made by parent adults, and larval mines, formed by the growing larvae. These tunnels form a particular pattern on the inner surface of the bark, which is distinctive for each species and usually very similar for each genus.

In starting an attack the male or female beetle bores an entrance tunnel through the bark, usually at a slightly upward angle. An egg tunnel is then constructed along the surface of the wood, cutting through the inner bark and often slightly or deeply scoring the sapwood. As the work progresses, fine boring dust and excrement are extruded through the entrance hole and collect in the bark crevices. In some cases pitch and sap exude from the entrance hole

and harden on the bark in various forms of pitch or resin tubes. Some species construct ventilation tunnels at intervals along the egg galleries. These are perpendicular to the egg galleries and extend through the bark to the surface or may end before the surface is reached. Boring dust is pushed out of those that are open at the surface of the bark, and they all are probably used as turning niches as well as for ventilation of egg tunnels. Later, as the mine progresses, these are sometimes plugged with boring dust.

The eggs, which are very small, are oval, round, or slightly elongate, and clear or chalky white. They are deposited in small cup-shaped cavities along the sides of the egg galleries. Usually a single egg is placed in each cavity or egg niche, which is closed with a plug of boring dust in such a way that the smooth cylindrical egg gallery is but little altered. Some species cut larger cavities or egg pockets and deposit from two to eight eggs in each. Others cut an elongated groove on one or both sides of the egg gallery and deposit the eggs in layers or rows.

The larvae or grubs are thick-bodied, always legless, cylindrical and curved, white or cream colored, with a distinct head and prominent dark-colored mandibles. At first the larvae and their mines are very small, but both increase in size as feeding progresses. The larval mines start away from the egg gallery more or less at right angles and may continue nearly straight or turn and run parallel to the egg tunnel. They are always packed with excrement and boring dust.

Transformation to the pupal stage takes place at the end of the larval mine in a specially constructed pupal cell. The pupae are soft, white, and unprotected. The antennae, mandibles, legs, and wing pads are clearly visible, and hairs and spines are often present on the various regions of the body. Gradually the pupae darken, turning light yellow and then brown, as the adult form is reached.

The adults, after a short hardening period, emerge and fly to attack new host trees, or congregate in cavities under the bark of the old host tree, or drop to the ground to hibernate. Some adults do a certain amount of feeding under the bark before emerging, and food tunnels made in this way are quite distinct in character from the regular egg galleries. Others upon emerging feed upon twigs or buds of other trees before again attacking the bark of a new host.

Normal or endemic infestations of bark beetles are present in practically all mature forests (*80*), causing an annual loss of a fraction of 1 percent of the timber on the area. Under conditions favorable to the insects, serious epidemics develop from these normal infestations in a very few years. Such outbreaks may be of short duration, or they may continue for many years, destroying large volumes of merchantable timber over extensive acreages.

If bark-beetle attacks are to be successful, the attacking insects must be present in sufficient numbers to overcome the resistance of the tree. Dead and dying trees offer little resistance to attack and for this reason they are usually chosen by the secondary species that are not capable of coping with a vigorous pitch flow. Light attacks by primary species on living trees often fail because the flow of pitch is so copious that the attacking beetles are overcome or driven

from their galleries. The oleoresins are known to be repellent and toxic to the beetles and so aid in resisting light attacks.

In the following discussion the bark beetles attacking western forest trees will be treated under their principal host trees.

Pine Bark Beetles

No group of commercially valuable trees in western forests has more insect enemies than the pines, and of these, bark beetles are the most numerous and destructive. The most aggressive bark beetles attacking western pines are the so-called "pine beetles" which belong to the genus *Dendroctonus*. Several species in this group are capable of attacking and killing normal healthy trees. The damage they do in western pine forests runs into millions of dollars annually.

The next most important group comprises the pine engraver beetles belonging to *Ips*, *Pityogenes*, and related genera. These beetles usually work under thinner bark and make very striking and distinctive forked or star-shaped gallery patterns. While they normally breed in weakened, dying, or felled trees, or in broken branches and slash, and are to that extent beneficial in hastening the disintegration of forest debris, they occasionally develop in sufficient numbers to become primary enemies of young trees and of the tops of older ones.

There is also a third group of bark beetles comprising a large number of species that are secondary in their attack and are seldom responsible for the death of any trees. Many of these are found feeding under the dying bark of pines that are being killed by other bark beetles, fire, or other causes and sometimes are confused with primary species. Space will not be taken for a description of all the bark beetles that may be encountered, for it is usually sufficient for all practical purposes if the forester learns to recognize those species of chief importance.

PINE BEETLES OR DENDROCTONUS BEETLES

The pine beetles which are members of the genus *Dendroctonus* (meaning tree killers) (*46*) make up by far the most destructive group of bark beetles attacking pine trees in North America. All species breed under the thick bark of the trunk of living or dying trees or in fresh stumps or logs of various pines. Some species prefer felled, weak, or dying pines, whereas others apparently prefer normal, healthy pines for their attack.

The adults are stout, cylindrical, dark reddish-brown to black bark beetles ranging from one-eighth inch to about three-eighths inch in length. The eggs, larvae, and pupae are similar to those of other bark beetles. These beetles are monogamous in habit and each pair constructs a single egg gallery which, starting from the outside, penetrates to the cambium and is extended between the bark and wood. Egg galleries differ in that some wind in a tortuous manner, crossing and recrossing the galleries made by other pairs of beetles, while others are straight and parallel to the grain of the wood. In all cases *Dendroctonus* egg galleries are always packed with boring dust, except for an inch or two at the end where the beetles are working. This will distinguish the work of the *Dendroctonus* beetles from that of other groups of bark beetles.

Trees attacked by *Dendroctonus* beetles can first be distinguished by reddish boring dust caught in bark flakes or crevices and around the base of the tree, or by pitch tubes that form on the bark at the mouth of the entrance tunnels, but in the case of heavily attacked or decadent trees pitch tubes are often either missing or are so small that they can be seen only from a short distance. Later, discoloration of the foliage furnishes a more noticeable evidence of attack. It is difficult, however, accurately to correlate the degree of discoloration with the status of brood development, as this varies with different tree species, regions, and seasons. The most conclusive evidences of attack are the egg and larval galleries on the inner surface of the bark. These form a pattern which is so characteristic for the work of each species that, when considered with locality and host tree, the identification of the species responsible for the attack is relatively simple.

The western pine beetle (*Dendroctonus brevicomis* Lec.) (*20*) is the most important insect enemy of ponderosa and Coulter pine within the range of these trees from Baja California, north into Oregon, Washington, Idaho, Montana, and western Canada. Other pines may be attacked under exceptional conditions. Normally it breeds in a few overmature trees, in windfalls, unhealthy trees, or in trees weakened by drought, stand stagnation, or fires. Under epidemic conditions it becomes aggressive and kills apparently vigorous trees of all age classes having bark sufficiently thick to protect it in its development. Trees under 6 inches in diameter are seldom attacked by this beetle nor does it breed in limbs. The heaviest losses of mature merchantable ponderosa pine have resulted from outbreaks of this insect in California, Oregon, and Washington. It is less important in the more northern limits of its range. Losses as high as 50 percent of the timber in 5 years have been recorded, and many large blocks of pine timber have been commercially ruined by its depredations (fig. 48).

The adult beetles are about the smallest of the western species of *Dendroctonus* and measure from one-eighth to about one-fifth of an inch in length. The larvae found in the outer bark are white, curved, and about the size of a grain of rice. Their work is distinguished from that of other bark beetles within the same range by the winding egg galleries which cross and recross each other, forming a network of irregular markings on the inner surface of the bark and on the surface of the sapwood (fig. 49). The larvae feed in the inner bark, working away from the egg gallery for about half an inch and then turn into the outer bark, where their development is completed. Flight and attacks start late in spring or early in the summer and continue until stopped by cold weather. There are from one to two generations annually in the northern part of the range and from two and one-half to four generations in the southern portion, where its activity continues almost without interruption throughout the year.

Woodpeckers, clerid beetles, and ostomatid beetles are important natural enemies of this insect, though its abundance is more often determined by climatic influences and the resistance of the host tree. Prolonged winter temperatures of $-20°$ F. and lower have been found to cause heavy brood mortality. Rapid, vigorous tree growth increases host resistance and discourages epidemics.

Direct control is recommended, particularly during developing epidemic conditions. The control measures consist in felling the infested trees; peeling and burning the bark late in the fall, or in winter or early spring; or peeling and spreading the bark for destruction of

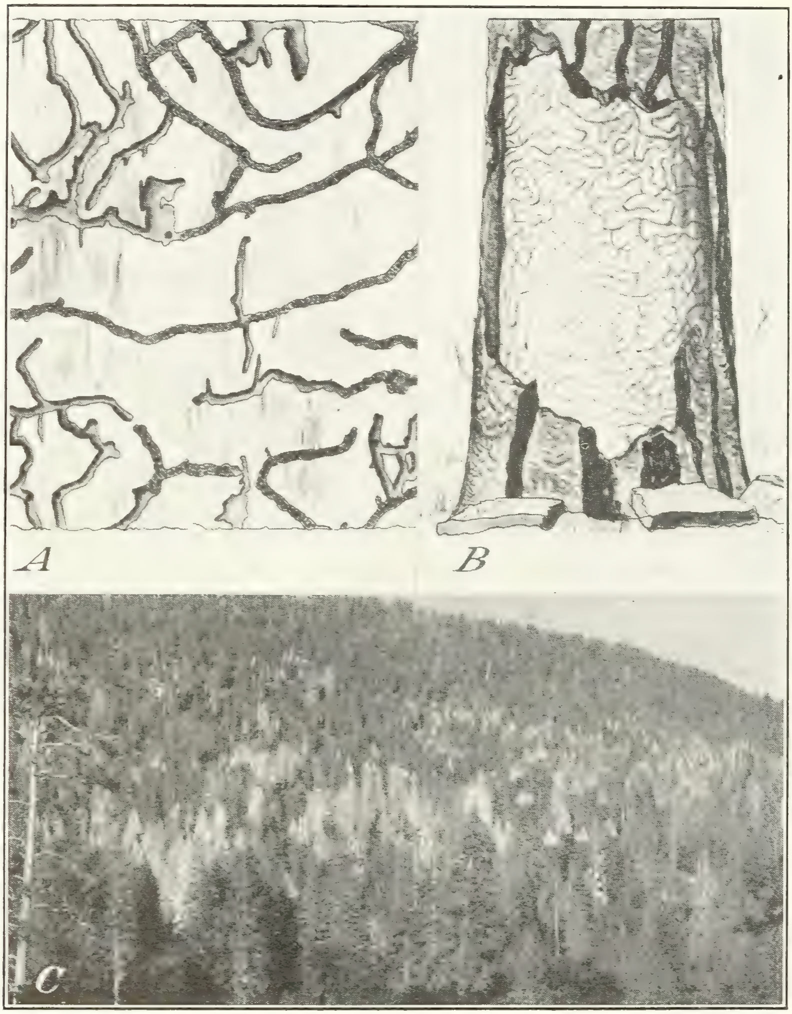

FIGURE 48.—Work of the western pine beetle (*Dendroctonus brevicomis*): *A*, Egg galleries on inner bark (half size); *B*, an infested tree trunk with bark removed (drawing by DeYoung); *C*, 1 year's loss in a ponderosa pine stand in California.

the broods by solar heat during the summer months. Control work has been successful in reducing infestations during critical periods, but cannot be relied on to eliminate them, and must be repeated until natural control factors become operative.

The southwestern pine beetle (*Dentroctonus barberi* Hopk.) attacks ponderosa pines in southern Colorado, southern Utah, Arizona, and New Mexico. A preference is shown for trees over 6 inches in diam-

eter and for those that, owing to drought or other causes, are in a weakened condition. It is most frequently found attacking mature, slow-growing trees on the lower fringe of pine growth and trees

FIGURE 49.—Typical winding egg galleries of western pine beetle marking the surface of the wood.

exposed on rocky ridges and dry southern slopes. This insect and the pattern of its galleries can scarcely be distinguished from those of the western pine beetle, but as methods of control are also the same.

more detailed descriptions are unnecessary. Since this beetle is less aggressive than the western pine beetle, however, control measures are seldom required.

The roundheaded pine beetle (*Dendroctonus convexifrons* Hopk.) attacks ponderosa pine throughout the same range as the southwestern pine beetle and often in company with it. This species usually enters the lower portion of trees previously infested by other bark beetles, but is sometimes primary in its attack upon decadent or weakened trees. The adults are about one-fourth inch in length and are a dark, shiny brown or black. The egg galleries are mostly vertical, long, slightly to markedly sinuous. The larval mines are usually in the cambium; pupation may take place either in the inner bark or concealed in the outer corky bark. Normally there is but one generation a year, and since the emergence is extended throughout most of the season there are never any great numbers of beetles attacking at any one time. The species is usually secondary and relatively unimportant.

The Arizona pine beetle (*Dendroctonus arizonicus* Hopk.) attacks and kills ponderosa pine and Arizona pine in central Arizona and probably other parts of the Southwest. Its appearance and habits are very similar to those of the southwestern pine beetle, and the methods of control are the same.

The Colorado pine beetle (*Dendroctonus approximatus* Dietz) attacks ponderosa, limber, Arizona, Chihuahua, and probably other pines in its range from northern Colorado and southern Utah south through Arizona and New Mexico. The dark-brown, elongate adults are from one-eighth to about one-fifth inch in length. They excavate a network of long, anastomosing, longitudinal, diagonal, and sometimes transverse galleries between the bark and wood of dying, felled, or occasionally healthy trees. The brood galleries are distinguished from those of most other species by the fact that the eggs are deposited in large niches on the side of the gallery farthest from the wood, rather than on the other sides of the gallery. Its work is therefore characterized by the absence of exposed larval mines on the inner surface of the bark. There is only one generation annually, and as a consequence it is not an aggressive species or of economic importance.

The mountain pine beetle (*Dendroctonus monticolae* Hopk.) (*30*) is very destructive to forest trees in the high mountains of California, Oregon, Washington, western Nevada, Idaho, western Montana, northwestern Wyoming, and British Columbia. In many places it has all but wiped out thousands of acres of lodgepole and western white pine (fig. 50), taken a heavy toll of valuable sugar pine, and attacked and killed ponderosa pines, whitebark pines, and other pines, mountain hemlock, and Engelmann spruce. Trees from 4 or 5 inches in diameter up to those of the largest size may be attacked. Attacks are usually heaviest along the main trunk of a tree from within a few feet of the ground up to the middle branches but may extend from the root collar very nearly to the top and into the larger limbs. During endemic infestations there is a tendency for the beetles to select the weaker, less vigorous trees for attack, but no such selection is apparent during epidemic conditions. Infested trees are recognized first by pitch tubes on the trunks of

trees and red boring dust in crevices and on the ground at the roots; later, by discoloration of the foliage, as it changes from normal green to light greenish yellow and then to red.

The adults are rather stout, black, cylindrical beetles from one-eighth to one-fifth inch in length. They excavate very long, perpendicular egg galleries (figs. 51 and 52) through the inner living bark, engraving both bark and wood. The galleries may be nearly straight or slightly sinuous, and sometimes, particularly in sugar pine, decidedly winding, and at the bottom of these galleries there is a short crook, or bend, 1 or 2 inches in length. The perpendicular portion of the gallery ranges in length from 12 to 36 inches and nearly always follows the grain of the wood.

FIGURE 50.—Lodgepole pine stand killed by the mountain pine beetle.

Eggs are deposited singly in cells or egg niches on alternate sides during the construction of the egg gallery. These hatch in a few days, and the small white larvae excavate short feeding tunnels at right angles to the egg gallery. These feeding tunnels vary in length and are exposed on the inner bark surface. When full grown, the larvae construct small pupal cells at the ends of the larval mines and in these transform to pupae and then to new adults. These pupal cells are usually exposed when the bark is removed, but in thick-bark trees they may be concealed in the inner bark. The new adults may bore away the intervening bark between pupal cells and congregate beneath the bark, prior to emergence, or individual emergence holes may be constructed directly from the pupal cells. Two or more insects often use the same emergence hole, and the emerging beetles often take advantage of cracks in the bark or holes resulting from woodpecker work.

The winter is passed in all stages of development except that of the pupa. These overwintering broods emerge in three well-defined

groups. (1) in June, (2) late in July and early in August, and (3) in September. New attacks are made immediately after emergence, and the resultant broods develop to new adults, mature larvae, or small larvae before the cold winter weather again stops develop-

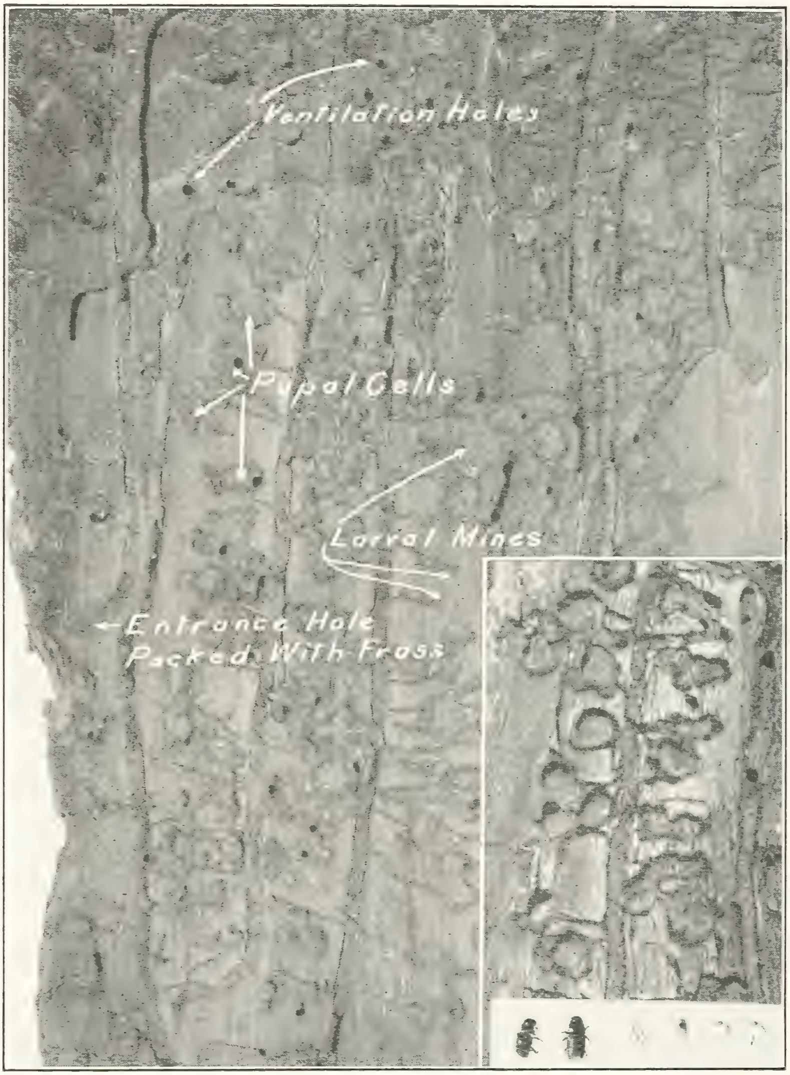

FIGURE 51.—Stages and typical work of the mountain pine beetle (*Dendroctonus monticolae*). Adults, larvae, and pupae, at lower right. Natural size.

ment. Normally there is only one generation a year, but owing to the uneven development there is considerable overlapping of the various broods, so insects in all stages may be found at any one time during the summer. Late fall, winter, or early spring is therefore the best time to carry on control work.

FIGURE 52.—Long vertical egg galleries are characteristic of mountain pine beetle work.

A clerid beetle (*Enoclerus*), a fly (*Medetera*), and a parasitic wasp (*Coeloides*) are the most active insect enemies. Woodpeckers also prey upon the species, and climatic conditions often are important as natural control agencies.

Direct control methods consist in felling the infested trees and either peeling the bark from the trunk or burning the bark either on or off the trunk. In the southern part of its range effective destruction of the broods in thin-bark lodgepole pine can be secured by felling the trees, trimming off the branches, and exposing the trunks to the sun's rays. Under certain conditions spraying the standing trees with fuel oil and burning them without felling has been found to be inexpensive and effective. Control operations are usually undertaken in the spring of the year. Peeling must be discontinued when the broods pupate. Burning can be continued until the start of emergence or until the fire hazard becomes too great.

FIGURE 53.—Severe damage to ponderosa pine in the Kaibab National Forest, Ariz., from attack by the Black Hills beetle. (Blackman.)

The Black Hills beetle (*Dendroctonus ponderosae* Hopk.) (*6*) is the most aggressive and destructive insect enemy of ponderosa pine in the Rocky Mountain region. It is distributed from the Black Hills of South Dakota (whence it received its name) to eastern Montana and south through eastern Wyoming, Colorado, Utah, Arizona, and New Mexico. Under normal conditions it is comparatively rare and found only in weakened, decadent trees. Periodically, however, its numbers increase to epidemic proportions and these sweep through the ponderosa pine stands, killing small to large groups in ever-increasing numbers, until as much as 50 to 90 per-

cent of the stand may be killed over large areas (fig. 53). Under such conditions it shows little discrimination and will attack and kill trees of all sizes, except the very smallest, apparently without regard for their health or vigor. Infested groups may contain from 2 or 3 to as many as 350 or more trees, and the size of the groups is a good indication of the severity of the infestation. On the edge of large groups there will nearly always be "pitched-out" attacks, indicating insufficient numbers in the attacking force. While ponderosa pine is the favored host, the beetles, particularly when epidemic, will attack all other pines within their range, such as lodgepole, limber, bristlecone, Mexican white, and piñon pine, and occasionally spruce. This beetle is so similar to the mountain pine beetle in appearance, habits, and the character of work as to be scarcely distinguishable from it.

The Black Hills beetle passes the winter as young to full-grown larvae and parent adults under the bark of trees attacked the previous season. The new brood of mature adults emerges late in July and in August, with some stragglers emerging in September. There is but one generation a year.

Direct control methods consist in felling the infested trees and peeling the bark or decking trees into piles and burning them. This work is usually done late in the spring and early in the summer. Peeling becomes ineffective as soon as the pupae have formed. Burning can be carried on later, but it will be halted by the approach of fire weather.

The Jeffrey pine beetle (*Dendroctonus jeffreyi* Hopk.) is an aggressive and at times very destructive enemy of Jeffrey pine in California. Although it often attacks trees that are apparently in a healthy condition it seems to prefer trees that are retarded in growth by droughts or defoliations. It rarely attacks felled trees, so does not breed in slash or windfalls to any extent. It confines its attacks to Jeffrey pine, and its distribution is therefore limited to that of its host tree.

The work of this beetle (fig. 54) is very similar to that of the mountain pine beetle. Reddish pitch tubes form at the mouth of the entrance holes, which are usually in crevices of the bark. There is usually a slight turn at the bottom of the egg gallery, which then proceeds up the tree in nearly a straight line following the grain of the wood. These galleries are usually 2 or 3 feet in length and are packed with boring dust. The eggs are placed in niches along the sides of the galleries, and the larvae work out from the egg gallery across the grain of the wood. The pupal cells are formed in the inner bark and are exposed to view when the bark is removed. The adults are black and about one-fourth of an inch in length, similar to, but considerably larger than the mountain pine beetle.

Trees are attacked most frequently in July or August. Eggs are laid, and some of the insects reach the new adult stage by winter. Parent adults, larvae, and new adults spend the winter under the bark. In the spring, development continues, and most of the new broods emerge during July and August. Thus there is ordinarily only one generation a year.

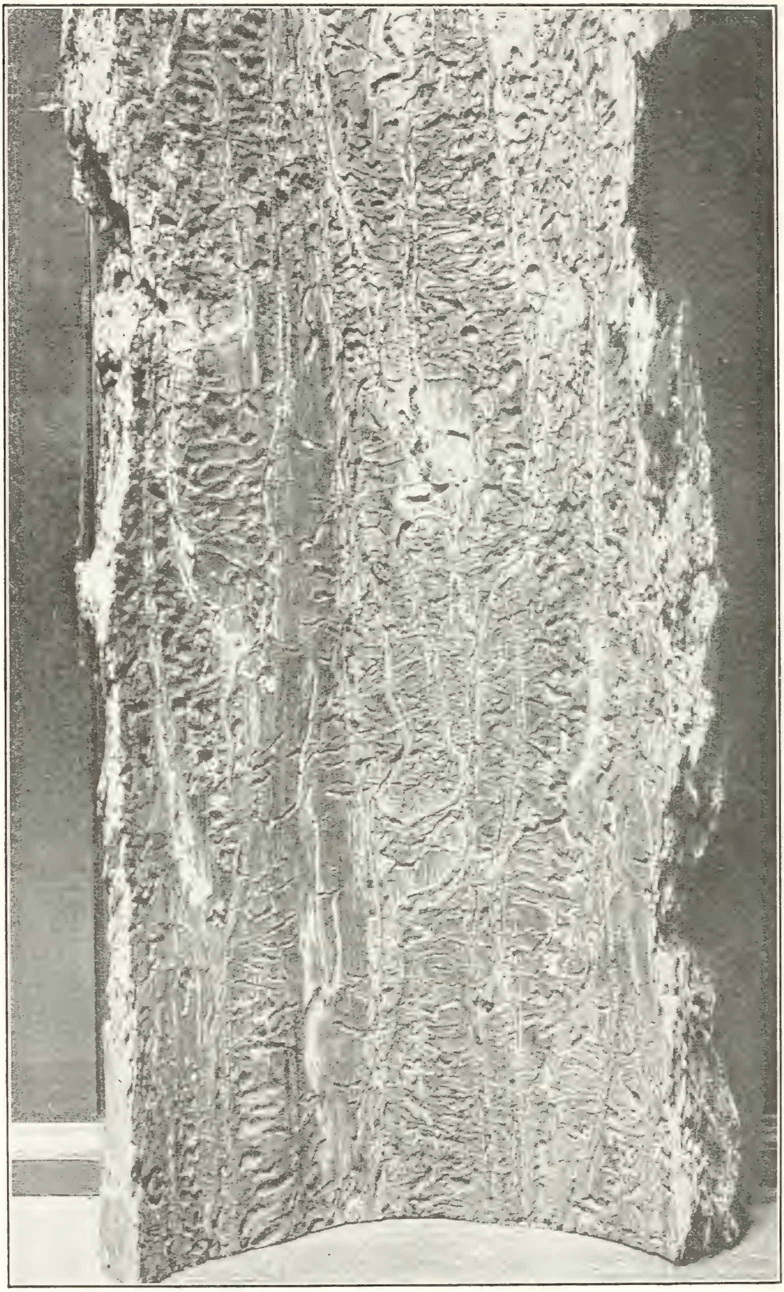

FIGURE 54.—Tunnels of the Jeffrey pine beetle on the inner bark surface of Jeffrey pine.

Either peeling the bark from infested trees before new adults form, or burning it, will kill the Jeffrey pine beetle. Methods used for the control of the western pine beetle are usually employed for this species also.

The lodgepole pine beetle (*Dendroctonus murrayanae* Hopk.) develops in large numbers in freshly cut stumps and attacks the base of old, weakened lodgepole pine in eastern Washington, Idaho, Montana, Wyoming, and Colorado. Ordinarily it is not an aggressive enemy, but it occasionally does kill overmature lodgepole pine left standing following tie operations, timber sales, or other cuttings. Fortunately such outbreaks die down at the close of the operation. In some instances trees are killed during the first year by the basal attacks of the lodgepole pine beetle, or it may require 3 or 4 successive years of attack before the resistance of the trees is sufficiently lowered to render them attractive to other bark beetles. In other cases they are abandoned by the insects before the attacks prove fatal. In any case, this basal damage to the tree may be considered as primary, as it is the first weakening influence.

The adults, which are about one-fourth of an inch in length, have reddish wing covers, while the prothorax and head are a dark brown or black. Their attacks, which are made on stumps or on the boles of the trees, usually within 4 or 5 feet of the ground, are easily recognized by the large pitch tubes, an inch or more in diameter, which form at the entrance holes. On reaching the cambium the attacking beetles construct short egg galleries, ranging from 5 to 12 inches or more in length, directly between the bark and wood. Eggs are deposited along the sides of these galleries and are separated from one another by boring dust. The larvae feed away from the egg gallery, keeping together in a common excavation or brood chamber. There are no separate or individual larval mines. Transformation to pupae and new adults takes place in cells constructed in the uneaten part of the inner bark or in cocoonlike structures composed of excrement in the brood chamber. The seasonal history has not been thoroughly worked out, but there appears to be one generation a year. Outbreaks of this insect are seldom of sufficient economic importance to warrant control measures.

The red turpentine beetle (*Dendroctonus valens* Lec.) (*36*) attacks the base of either injured, dying, or healthy trees, or freshly cut logs and stumps of all pines and occasionally spruce, larch, and fir throughout the western and northeastern part of the United States and southern Canada. Ordinarily it is not considered an aggressive tree killer but it does do considerable primary damage and so weakens trees as to make them more susceptible to attack by other bark beetles. In some cases, such as with Monterey pine in California, it causes sufficient damage to result in the death of the tree. It is particularly active around logging operations, where it not only works in the stumps, but will often produce catfaces on the bases of trees left in the reserve stand.

The adults are the largest bark beetles of this genus, measuring from one-fourth to three-eighths of an inch in length, and are distinctly reddish in color. They are often called barber beetles by woodsmen, on account of their ability to clip hairs, and are commonly, though erroneously, thought to be the bark beetles responsible

for the destruction of pines. Their attacks are characterized by large reddish pitch tubes that form at the point of attack. On burrowing under the bark the beetles excavate an irregular longitudinal egg gallery between the bark and the wood. These galleries range from a few inches to several feet in length, as Patterson reports finding one gallery extending underground along a root for 15 feet from the point of entrance. The gallery is more or less packed with frass, and eggs are laid in groups or masses at intervals along the sides. The larvae feed out through the inner bark in mass formation, producing a cavity between the bark and wood which ranges from a few square inches to a square foot or more in area. These chambers are often filled with a resinous liquid that apparently has no injurious effect upon the developing broods. Transformation to the adult stage occurs within pupal cells constructed in the boring dust of the brood chamber or in short mines along its margin.

There are one or more overlapping generations annually, depending on the locality and season. In the more southern range of the beetles it can be found in all stages of development at nearly any season of the year. The heaviest attacks occur in midsummer, and the winter is passed as larvae, new adults, and parent adults, in trees and stumps attacked the previous season.

Though this beetle is seldom of serious importance in commercial timber stands, should control measures become necessary, the broods could be destroyed by removing the bark from fresh stumps and from the base of infested trees. For the protection of individual park or shade trees, the damage can be halted by cutting out the attacking beetles with a knife or chisel as soon as pitch exudations indicate their presence. Successful control also has been obtained by injecting carbon disulphide into the galleries.

THE PINE ENGRAVER BEETLES

Smaller species of bark beetles which work in the trunks and larger branches of pines, and construct egg galleries which radiate from a central nuptial chamber and form distinctive patterns, are frequently referred to as the pine engraver beetles. These belong to *Ips*, *Pityogenes*, *Orthotomicus*, and other related genera.

These bark beetles normally feed on the cambium of weakened, dying, or recently felled coniferous trees and are capable of developing in large numbers in such material as windfalls, snowbreak, logging and road slash, and also the tops of trees killed by *Dendroctonus* or other beetles. They are beneficial insofar as they help in the reduction of forest debris, but if large quantities of favorable host material are available they frequently develop and emerge in such numbers as to attack and seriously injure or kill adjacent groups of healthy trees. Under such conditions they are often exceedingly destructive to seedlings, saplings, and young second-growth poles, and the tops of older trees. While *Dendroctonus* beetles prefer to attack the thick bark of the main trunk and are, therefore, more destructive to mature trees, the engraver beetles usually select thin-bark trees for attack, thereby qualifying as primary enemies of younger trees. Some species are frequently found working in association with *Dendroctonus* beetles, in which case their attack is usually of a secondary nature, although in some cases, top-killing of trees

by these engraver beetles precedes and possibly attracts subsequent infestation by *Dendroctonus* beetles. With the removal of mature forests, to some it seems quite likely that this group of bark beetles will outrank the *Dendroctonus* beetles in destructiveness to the second crop of pines.

The Ips or engraver beetles

The first evidence of attack by this genus is yellow or reddish boring dust in bark crevices or little piles of such dust around the entrance holes or on the ground beneath. Pitch tubes are seldom formed, and the boring dust is usually dry and free from pitch. Soon after a tree has been attacked the foliage fades and turns from green to yellow, sorrel, and red. Upon removing the infested bark the tunnels of the engraver beetles will be found grooving the inner bark surface and slightly marking the sapwood. The egg galleries differ from those of the *Dendroctonus* beetles in that instead of being tightly packed with boring dust they are open runways in which the adult beetles are free to travel the entire length. A second difference is their polygamous social habit of constructing a central nuptial chamber from which fork or radiate several egg galleries. In many cases the pattern of the completed work is sufficiently distinctive to identify the species responsible. However, some species cannot be recognized in this way and can be distinguished only by characters in the adult beetles.

The adults are small, reddish brown to black, often shiny, cylindrical bark beetles ranging from one-eighth to approximately one-fifth of an inch in length. A distinguishing feature is the pronounced concavity on the posterior end, which is margined with from one to six pairs of toothlike spines. The small, white, legless larvae differ slightly from *Dendroctonus* larvae in that the body is more tapering and is thicker at the forward end than toward the rear.

Attacks are made by these bark beetles with the coming of warm weather in the spring. An adult male bores through the bark and constructs a small cell or nuptial chamber in the inner bark. Several females then join in the work and each constructs an egg gallery in which eggs are laid in niches along the sides. The larvae, upon hatching, feed in the inner bark and work away from the egg galleries, leaving gradually widening, excrement-packed tunnels behind them. When their feeding is completed oval pupal cells are formed, in which the transformations from larvae to pupae and then to adults take place. From the time of attack until the emergence of the first of the new brood ordinarily requires from 42 to 68 days. From two to five generations of these beetles may develop during the summer, depending on the altitude, latitude, and species, there being considerable overlapping of generations. The winter is usually spent in the adult stage, although occasionally in the egg or larval stage. Some species congregate in large groups under the bark of standing trees killed the previous year and feed to a limited extent on the dry, dead, inner bark. Others emerge and hibernate under the bark of old stumps, among the bark scales, or in crevices and litter at the base of old brood trees.

Engraver beetles have a number of predacious and parasitic enemies but it appears that these do not affect the numbers of the beetles

so much as does the lack of suitable host material. Given a quantity of freshly cut slash or windfalls, a large beetle population is almost certain to be produced but it will not long survive after the supply of this material is exhausted.

Since outbreaks in standing, healthy trees are sporadic and of short duration, the destruction of the broods in these trees, through the application of control methods, seldom contributes a great deal toward reducing the damage. Efforts should be directed toward preventing outbreaks by eliminating all situations favorable to the development of excessive progeny. Thus, slash should be piled and burned before the *Ips* beetles emerge, or scattered in the open where the sun will dry it out and make it unsuitable as a breeding medium. If it should be necessary to destroy broods in standing trees, the most economical and effective method is to fell the trees and burn or scorch the infested bark. A large number of species of this genus are recorded from western pines, all very similar in appearance and habits, so only a few of the more common species need be mentioned here.

The western six-spined engraver (*Ips ponderosae* Sw.) is a secondary enemy of ponderosa pine, which for the most part attacks trees that have been felled or those dying from attacks of more primary species of bark beetles. The adults are about one-fourth inch in length, reddish brown to black, with six spines on each side of the elytral declivity. The gallery pattern consists of from two to five egg galleries extending up and down the tree from the central nuptial chamber. Though the pattern is similar to that of *I. oregoni*, the galleries are distinctly wider. This beetle has been recorded from Arizona, California, Montana, and South Dakota, and undoubtedly is present in other Western States.

The California five-spined engraver (*Ips confusus* Lec.) is destructive to tops of mature trees, small poles, and the saplings of various pines in California and southern Oregon west of the Cascade and Sierra Nevada ranges. It breeds readily in slash and felled logs, and the broods from such material often cause extensive damage to the young pine growth in the vicinity. It commonly attacks ponderosa pine, sugar pine, western white pine, Coulter pine, Monterey pine, and less frequently other pines within its range.

The adults are reddish brown to pitch black, about one-eighth inch long and with five spines on the margin of each side of the elytral declivity. The egg galleries usually comprise from three to five nearly straight tunnels radiating from a central entrance chamber. The typical form has three galleries in the shape of an inverted Y. These galleries are not packed with boring dust and are usually from 5 to 10 inches long. Attacks are started early in the spring and from two to five generations of beetles may develop during the summer. In the northern part of the range, at an elevation of about 3,000 feet, there are usually two summer generations which develop in fallen logs and a third, or overwintering generation, which develops in standing trees. At lower altitudes and in the southern part of the range there are from three to five summer generations. The beetles overwinter mostly in the adult stage, under the bark of recently killed trees and probably in crevices and under litter on the ground.

Some attempts have been made in California to control outbreaks of this beetle in young pine stands by felling the trees and burning the infested bark much as is done for the control of the western pine beetle. Usually such methods are not warranted, as outbreaks are sporadic and can be avoided if roadway, line, or other slash is burned before the beetles emerge, or in logging operations if a continuous supply of fresh material is provided to absorb developing broods.

The Arizona five-spined engraver (*Ips lecontei* Sw.) is the southwestern form of *I. confusus.* It attacks ponderosa and other pines in the southern Rocky Mountain region and at times is exceedingly destructive. Its characteristics and habits are very similar to those of its near relative, and the methods of control are the same. Recently some rather extensive operations have been carried on in Arizona to control this beetle.

The Vancouver ips (*I. vancouveri* Sw.) is also closely allied in character and habits to *I. confusus*, but is slightly larger. The adult beetles are reddish brown to black, about one-fourth inch in length, and with five spinelike teeth on the margins at each side of the concave elytral declivity, which is densely clothed with long, slender hairs. These beetles usually attack decadent or weakened western white pine, sugar pine, foxtail pine, lodgepole pine, and Sitka spruce throughout the Northwest, but under favorable conditions will attack apparently healthy trees. The gallery pattern is of a radiating, longitudinal type with three to five short egg galleries extending up and down the tree from the nuptial chamber. There are apparently two but possibly three generations a year.

The Cloudcroft ips (*I. cloudcrofti* Sw.) is a secondary enemy of pines in the high mountains of New Mexico. It is a slender species with five pairs of spines on the elytral declivity and is closely related to *I. confusus* in character and habits.

The emarginate ips (*I. emarginatus* Lec.) is most frequently found associated with the mountain pine beetle in its attacks on ponderosa pine, lodgepole pine, and sugar pine, and with the Jeffrey pine beetle in Jeffrey pine, but is quite capable of and occasionally does kill trees on its own account. This is the largest western species of *Ips.* Its range extends through California, north to southern British Columbia, and east through Idaho to western Montana. The adults are dark-brown, cylindrical bark beetles about one-fourth inch in length, with three prominent spines along each side of the elytral declivity, and a fourth nearly obsolete spine. Their work is characterized by the long, straight, nearly parallel egg galleries from 2 to 4 feet in length, which run up and down the tree and connect at different points (fig. 55). Owing to the similarity in length and width of the egg galleries, its work is often confused with that of the mountain pine beetle with which it is so often associated. However, the presence of a nuptial chamber and the absence of packed boring dust in the *Ips* galleries will distinguish their work. In the northern part of its range this species has two complete generations a year, while in the southern part there are a number of summer generations with considerable overlapping of broods. Control work has included this species when in association with more aggressive bark beetles, but no separate control ever has been required.

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Knaus' ips (*I. knausi* Sw.) attacks lodgepole pine, ponderosa pine, and Arizona pine through the pine belt of Arizona, New Mexico, and Colorado. It is usually a secondary enemy. In its habits, char-

FIGURE 55.—Galleries and pupal cells of the emarginate ips (*I. emarginatus*) on the inner bark surface of ponderosa pine.

acter of work, and appearance it closely resembles its near relative, *I. emarginatus*, and may be considered the southern Rocky Mountain form of this beetle.

The smaller western pine engraver (*Ips latidens* Lec.) usually confines its attacks to the tops and limbs of dying or weakened pines and seldom causes any primary injury. Under favorable conditions, however, it has demonstrated its ability to kill trees, particularly those weakened by mistletoe or drought, and in some instances even healthy trees of small diameter. It is quite common in the tops of lodgepole pines killed by *Dendroctonus* beetles, and during severe epidemics of the mountain pine beetle it often develops in such numbers as to attack and destroy many small trees throughout the area. The adults are the smallest of the western species and are about one-eighth inch in length. They are distinguished by having three small, spinelike teeth along the margin of the elytral declivity, which is nearly vertical. Its typical work consists of from two to five rather short, sometimes curved, egg galleries radiating from the central nuptial chamber. It is distributed throughout most of the Western States, where it attacks ponderosa, sugar, digger, lodgepole, western white, and probably other species of pine. *I. guildi* Blkm. is a closely related form which attacks lodgepole and probably other pines in Colorado and the central Rocky Mountain region.

The sawtooth pine engraver (*Ips integer* Eichh.) is distributed throughout the Western States, but is found most commonly in the Rocky Mountain region. It generally breeds in weakened or felled ponderosa pine, lodgepole pine, western white pine, and western larch, but under favorable conditions it may become primary. The stout, brownish-black adults are about one-fifth of an inch in length and have four spinelike teeth along the margin on each side of the concave elytral declivity. This species constructs three or four straight longitudinal egg galleries that fork from the common entrance or nuptial chamber. The egg niches are so thickly and evenly spaced along the sides of the egg galleries as to give these a sawtoothed appearance—a distinctive feature of this species' work.

The California pine engraver (*Ips plastographus* Lec.) is a species, closely related to *I. integer*, which prefers to attack the trunks and branches of felled Monterey, Bishop, and lodgepole pine, but at times also attacks weakened or dying standing trees. It is not often primary in its attacks, but is usually associated with the Monterey pine engraver and the red turpentine beetle in the killing of living trees or trees injured by fire or other causes. It is found through the range of its host trees in the coastal belt of middle California and in the Sierras. The adults are about one-fifth of an inch in length, with four pairs of spines on the posterior margin of the wing covers. The work pattern is very similar to that of *I. confusus*, the typical form having three egg galleries from 5 to 15 inches in length, issuing from each entrance chamber. There are from three to five generations annually, depending on the locality and season.

The Oregon pine engraver (*Ips oregoni* Eichh.) is probably the most common *Ips* beetle found throughout the Western States, where it attacks ponderosa pine, lodgepole pine, sugar pine, Jeffrey pine, digger pine, and probably other species (fig. 56). Large numbers develop in such host material as windfalls, freshly cut logs, pieces of slash over 2 inches in diameter, and in the tops and limbs of trees killed by *Dendroctonus* beetles. When conditions are favorable and suitable host material is plentiful, they frequently develop

in such numbers as to become aggressive in their attacks on healthy living trees. However, such outbreaks are usually of short duration and seldom last more than one season. The most frequent damage

FIGURE 56.—The typical galleries of the Oregon pine engraver score the sapwood.

is in the killing of young replacement trees from 2 to 8 inches in diameter and the top-killing of older trees.

The adults are reddish brown to nearly black, about one-sixth of an inch in length, and with four small teeth along the margins on each side of the elytral declivity. A typical sample of their work

shows three or four egg galleries forking from a central nuptial chamber and running more or less longitudinally with the grain of the wood for a distance of 5 to 10 inches. There may be anywhere from one to seven females to each male, with as many egg galleries radiating from the one nuptial chamber. There are from two to four generations of this species a year, depending on the locality and the length of season. The parent adults often emerge and make a second and even a third attack that results in a confusing overlapping of broods. Preventing these beetles from becoming too numerous through timely slash disposal will do more to prevent damage than the application of control measures after damage has occurred.

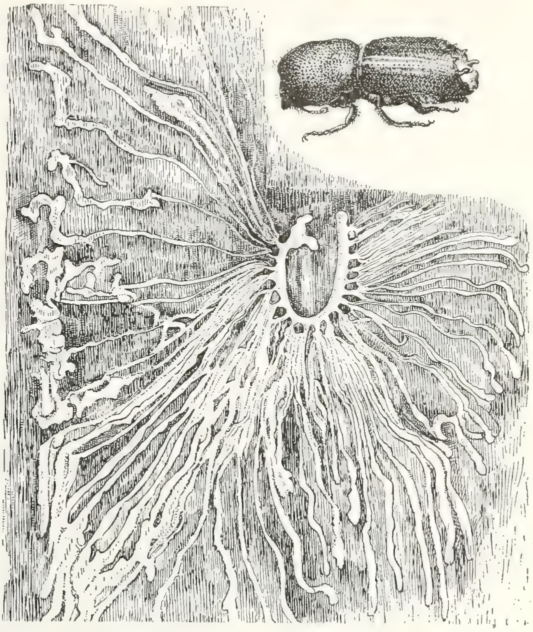

FIGURE 57.—Monterey pine engraver (*Ips radiatae*): Adult (× 8) and pattern of work on sapwood.

The Monterey pine engraver (*Ips radiatae* Hopk.) attacks living, injured, dying, and recently felled Monterey, Bishop, knobcone, Jeffrey, lodgepole, and whitebark pines from central California northward to British Columbia and eastward to Idaho and Wyoming. It is usually a secondary enemy and associated with other bark beetles in its attack, but at times may become primary, especially in plantations of Monterey pine. The adult beetles are about one-fifth of an inch in length, dark brown and shining, with parallel sides and one very prominent spine on the end of each wing cover. The egg galleries are curved or S-shaped, with three or four larval mines issuing from each egg pocket (fig. 57). The rapidity of development and the number of generations will vary with different seasons and localities. Usually there are one or two summer generations and an overwintering generation. The beetles overwinter beneath the bark of trees killed during the previous summer, mostly as adults, but also as larvae and pupae. Some extensive control operations have been undertaken in California to suppress outbreaks of this beetle that developed from roadway slashings.

Pityogenes and other wood engraver beetles

The small bark beetles belonging to the genus *Pityogenes* are sometimes referred to as "wood engravers." They usually are of secondary importance and attack the tops, limbs, and twigs, of

weakened, dying, and newly felled trees; but, like other secondary species, under favorable conditions they may develop in sufficiently large numbers to attack and kill small trees growing in the vicinity of their breeding place. The adults are small, dark-brown beetles, with small, spinelike teeth along the margin of a slightly concave elytral declivity. They are polygamous and excavate numerous galleries under the bark, which radiate from a central, more or less circular, nuptial chamber.

Pityogenes carinulatus Lec. breeds in ponderosa, lodgepole, whitebark, Jeffrey, and probably other pines and is distributed over nearly all of the Western States. The adults are slender, reddish-brown bark beetles about one-eighth inch in length. The females have three small, spinelike teeth along each margin of the elytral declivity, whereas the males have only two declivital teeth on each side, the first pair strongly developed into prominently curved spines. Their gallery pattern consists of from 8 to 10 or more rather slender egg galleries from 1 to 2 inches in length, radiating from a circular entrance chamber.

Pityogenes knechteli Sw. is a stout species about one-eighth inch long, commonly found associated with *Ips* and *Dendroctonus* beetles under the thin bark of lodgepole pines in the Western States and in British Columbia, and is sometimes responsible for the destruction of small patches of lodgepole pine in reproductions. The work consists of from three to five egg galleries 1½ to 3 inches in length, radiating from the central nuptial chamber.

Pityogenes fossifrons Lec. is a species occasionally found working in the tops and limbs of weakened or dying western white pine and lodgepole pine from California northward to British Columbia and eastward to Idaho. Its attacks are seldom primary, though it sometimes attacks western white pine reproduction. The adults are small, brownish-black bark beetles approximately one-eighth inch in length with three very small spines along each margin of the elytral declivity. Their gallery pattern consists of four or five egg tunnels 1 to 1½ inches in length, radiating from the entrance or nuptial chamber (fig. 58).

Several other species of small engraver beetles may be encountered under the bark of pines. *Orthotomicus ornatus* Sw. is a very small species about one-eighth inch in length. The elytral declivity is slightly concave, with three pairs of small teeth, the second and third pairs of teeth larger on the males. Their work is similar to that of *Pityogenes*, and they frequently are found under the thick bark of ponderosa, Jeffrey, and lodgepole pines in small mines intermingling their work with that of the pine beetles. Some species of the genus *Pityophthorus* are occasionally found under the thick bark of dying pines, and may be responsible for the death of weakened trees (p. 31).

Fir Bark Beetles

The balsam firs (*Abies* spp.) and Douglas fir (*Pseudotsuga taxifolia*), as well as pines, have their full share of bark-beetle enemies (*19*). In general the destructive species are different from those attacking pines, though many of the secondary species may be the same. Douglas fir growing under favorable conditions in the com-

mercial stands of western Oregon and Washington seems to be quite resistant to bark-beetle attack, and serious damage is rarely found. At times, however, this tree suffers from bark beetles, even in this region of favorable growth. In the eastern portion of the Douglas fir range, where growth conditions are less favorable and the timber is of inferior quality, bark-beetle outbreaks of disastrous proportions

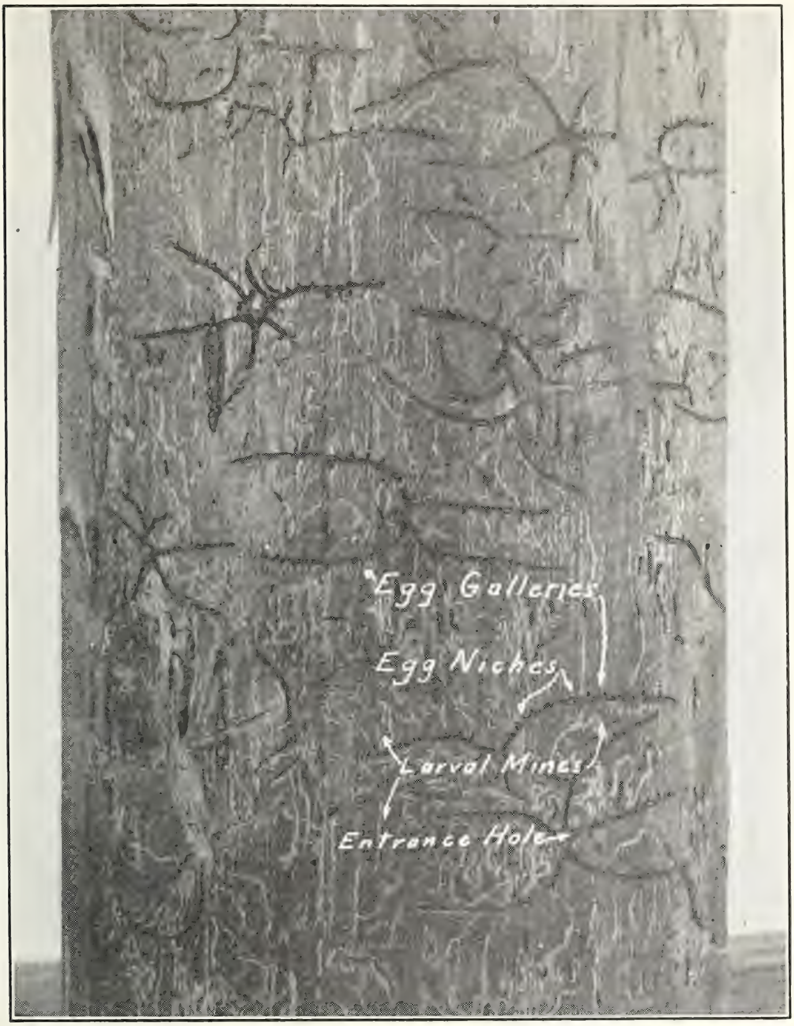

FIGURE 58.—Typical galleries and egg niches of *Pityogenes fossifrons*.

are not an uncommon occurrence. The Douglas fir beetle (*Dendroctonus pseudotsugae*) is the most common offender and causes the bulk of the damage. Small Douglas firs are frequently killed by the fir engraver beetles, particularly in situations where large numbers of these small beetles have developed in windfalls or slash. The engravers usually responsible for this type of damage are *Scolytus unispinosus* or *Pseudohylesinus nebulosus*.

The balsam firs are very susceptible to bark-beetle damage, and in certain years outbreaks sweep through fir stands and kill a high percentage of the trees. In such cases it is not uncommon to see entire hillsides turn red with the discolored foliage of dying trees. Since balsam firs are not of great commercial value within our western forests, no estimates have been made as to the extent of such damage.

In addition to aggressive tree-killing fir bark beetles, there are also a large number of secondary species that breed in dying or dead trees, slash, and broken tops. These, under exceptionally favorable circumstances, may become destructive to living trees.

The Douglas fir beetle (*Dendroctonus pseudotsugae* Hopk.) is the most important bark-beetle enemy of Douglas fir throughout its range in the Western States. It also attacks western larch, western hemlock, and bigcone spruce. Normally it confines its attacks to felled, injured, or weakened trees and is not of great importance. At times, however, it becomes aggressive and kills apparently healthy, mature trees, singly and in groups, over extensive areas. Some serious epidemics have occurred in the Rocky Mountain region, particularly where trees were weakened by drought, fires, or defoliations. In the commercial Douglas fir region of Oregon and Washington outbreaks are of less frequent occurrence, although the killing of groups of mature trees in second-growth stands is not uncommon.

Reddish or yellow boring dust caught in bark crevices or around the base of trees gives the first evidence of attack by the Douglas fir beetle, as no pitch tubes are formed. The adults are reddish to dark brown, often black, beetles about one-fifth of an inch long and very similar to other *Dendroctonus* beetles (p. 98) except for their reddish color and their covering of conspicuous long hairs. These beetles work in pairs and construct egg galleries which are mostly in the inner bark, though they also slightly etch the sapwood. Typical galleries are perpendicular, usually straight or slightly sinuous (fig. 59) and average about a foot in length, though they may range from 6 to 30 inches. The eggs are laid in masses of from 10 to 36. These masses are in grooves at alternate intervals along the sides of the gallery. The larval mines diverge from the egg groups and are extended through the inner bark close to the wood. They expand as the larvae grow, so the completed work from each group of eggs is somewhat fan-shaped. The pupal cells, which are constructed at the ends of the larval mines, may be exposed when the bark is removed from the tree, or they may be concealed in it, depending on the thickness of the bark. In these cells the transformation from larvae to pupae and then to new adults takes place. The new adults bore away the intervening bark between pupal cells and congregate, sometimes for rather long periods, beneath the bark. Finally they bore through the bark to the surface, emerge, and fly to make their attack on other trees.

Ordinarily the Douglas fir beetle passes the winter in the adult stage, although small to mature larvae also may be found. The overwintering adults emerge rather early in the spring, but the delayed broods mature and emerge at any time throughout the summer months. It is also possible that some of the young overwintering

larvae do not have time to complete their development before cold weather overtakes them in the fall, and consequently they are obliged to spend another winter in the host tree. One generation of beetles

FIGURE 59.—Galleries of the Douglas fir beetle on inner bark surface.

a year is probably the normal rate of development, but there are considerable overlapping and retardation of broods, somewhat obscuring the demarkation between generations.

The usual method of direct control is to fell the tree and cut the infested bole into logs, which are then decked and burned. As a large percentage of these insects overwinter as adults and emerge early in spring, fall control is the most effective.

THE FIR-ENGRAVER BEETLES

There are a number of small species of bark beetles, belonging to *Scolytus*, *Pseudohylesinus*, and other related genera, which commonly work under the bark and score the sapwood of dying, broken, or felled firs, but which at times may become so abundant and aggressive as to attack and kill small trees. This entire group may be referred to as "fir engraver beetles."

FIGURE 60.—Work of the Douglas fir engraver (*Scolytus unispinosus*).

Members of the genus *Scolytus*, are small, shiny, dark, or nearly black bark beetles, which are easily recognized by the concave appearance of the posterior ventral surface of the abdomen. The adults feed for some time by making feeding pits in the twigs and later attack in pairs and construct short egg galleries, usually from a central entrance chamber. The larvae work out at right angles from the egg gallery and bore through the phloem and inner bark, usually deeply scoring the sapwood. Some members of the genus are exceedingly destructive to balsam firs. Others work in Douglas fir, hemlock, spruce, or even in broadleaved trees.

The Douglas fir engraver (*Scolytus unispinosus* Lec.) is commonly found attacking weakened, injured, dying, or recently killed Douglas fir in the Pacific Coast and Rocky Mountain States and southwestern Canada. Sometimes it is a primary enemy of young Douglas firs. The adults are small, black, cylindrical, shining bark beetles about one-eighth inch in length, with a long spine projecting from the middle of the nearly perpendicular face of the ventral declivity. The typical egg gallery follows the grain of the wood and may range in length from 1¼ to 3 inches. A short entrance tunnel leads into the main gallery, at an angle of 45°, and a small nuptial chamber is constructed at the juncture (fig. 60). The larvae work out at more or less of a right angle from the egg gallery, and then work up or down the tree so that the mines will not cross one another. The winter is spent in the egg and young larval stages. Emergence of adults takes place late in April, in May, June, and July. There appear to be two generations annually.

The fir engraver (*Scolytus ventralis* Lec.) is found attacking the balsam firs in all the Western States and in British Columbia, and at times has been exceedingly destructive to white fir stands in California and Oregon. The adult is a short, black bark beetle about one-eighth inch in length, without a prominent spine on the ventral declivity. The egg galleries are excavated in the inner bark and cut transversely across the grain of the wood, which they score rather deeply for a distance of from 2 to 6 inches on both sides of a central entrance chamber.

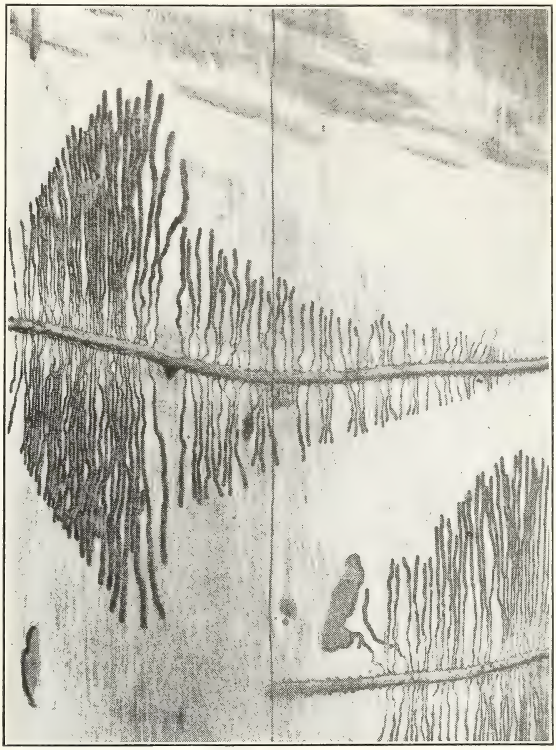

FIGURE 61.—Egg galleries and larval mines of the fir engraver (*Scolytus ventralis*).

Eggs are laid in niches along both sides of these galleries and the larvae, on hatching, work up and down the bole (fig. 61), extending their individual larval mines for a distance of 5 to 7 inches. A brown stain of the cambium caused by a fungus is always found in the area in which the larvae feed. Pupation occurs in the inner bark at the end of the larval mines, and the new adults bore directly to the surface of the bark when ready to emerge. Frequently green trees are attacked and new broods develop and emerge without destroying enough of the cambium to cause the death of the tree. The patch of dead cambium heals over and leaves only a brown pitch pocket in the wood to mark where the injury occurred. Some wood sections have shown as many as seven such attacks during the life of the tree, which indicates that a certain amount of activity by this beetle is constantly going on in the forest. Trees are attacked during the summer months, and the eggs hatch and larvae develop before winter. The winter usually is passed in the larval stage, and the new broods emerge the following year. There is normally but one generation of these beetles annually. Because of the sporadic character of outbreaks and the possible presence of healthy broods in living trees no methods of control appear practical.

Other species of *Scolytus* which may be found in western firs include *S. subscaber* Lec., a large species which makes E-shaped

galleries in the limbs of balsam firs; *S. praeceps* Lec., a small species about one-eighth inch in length, which attacks the limbs and small tops of white fir and other firs in the Western States; and *S. monticolae* Sw., about one-eighth inch in length, which is recorded by Swaine as attacking western white pine and Douglas fir in British Columbia.

Some of the species of the genus *Pseudohylesinus* are also quite frequently found in various firs. They usually are secondary in habit but at times some species are destructive. Their work is very similar to that of *Scolytus* in that the typical egg gallery consists of two short, straight branches from a central entrance tunnel. The work usually can be distinguished from *Scolytus* in that no enlarged nuptial chamber, scoring the sapwood or visible on the inner surface of the bark, is constructed, as is the case with *Scolytus*. Another distinguishing feature between these two genera is that the wing covers of *Pseudohylesinus* are densely covered with scales, and therefore are dull in appearance instead of shiny. Moreover, the beetles are nearly oval in outline and do not have the concavity at the rear of the abdomen which is such a distinctive feature of *Scolytus*.

FIGURE 62.—Adults and galleries of the Douglas fir hylesinus (*Pseudohylesinus nebulosus*), natural size.

The Douglas fir hylesinus (*Pseudohylesinus nebulosus* Lec.) is frequently found attacking recently felled or injured small Douglas firs through the range of this tree from British Columbia to central California. It seems to prefer the thin bark of saplings, or poles, or limbs of larger trees, and frequently kills trees of small diameter. The adults are small, grayish to yellowish-brown, variegated bark beetles about one-eighth inch in length. Usually a short longitudinal egg gallery is constructed in the cambium layer, often with two branches, originating from a central entrance tunnel, one up and one down the trunk, parallel with the grain of the wood (fig. 62). Their work is very similar to and easily confused with that of *Scolytus unispinosus*, but is distinctive in that no well-defined

nuptial chamber is visible on the inner surface of the bark. The larval mines diverge from the egg gallery and end in pupal cells in the inner bark. There appear to be two generations a year.

The grand fir bark beetle (*Pseudohylesinus grandis* Sw.) attacks the trunks or limbs of weakened or dying Douglas fir, lowland white fir, and white fir, and is usually of secondary importance. The adult beetles are about one-eighth inch in length, rather stout, elongate-oval, densely covered with brown and gray scales which sometimes form V-shaped markings on the wing covers. They work in pairs and each pair constructs a short, transverse egg gallery for 2 or 3 inches, sometimes on only one side but more frequently on both sides of the entrance tunnel. The work is very similar to that of *Scolytus ventralis* except that the egg gallery is narrower, not so uniformly straight, and without the well defined entrance chamber. There are one or two generations a year, depending on the locality.

The fir root bark beetle (*Pseudohylesinus granulatus* Lec.) is a larger, very dark reddish to black species about one-fifth of an inch in length, with very rough elytra and prominent striae. It is a secondary enemy of grand fir and white fir, working under the bark of dying or dead trees, particularly at the base and in the roots of small trees. It is distributed from California to British Columbia.

The noble fir bark beetle (*Pseudohylesinus nobilis* Sw.) is similar to *P. grandis*, approximately one-eighth inch in length, and is found breeding in dying noble fir.

Some of the species of *Dryocoetes* are found working under the bark of firs. While they are usually secondary enemies, they at times attack and kill apparently healthy trees.

The western balsam bark beetle *Dryocoetes confusus* Sw. is probably the most destructive member of the group and is quite often found attacking alpine fir and sometimes other species of fir and spruce. The adults are rather short, reddish-brown bark beetles about one-eighth inch in length. They construct a small, circular nuptial chamber under or in the bark, with several radiating egg galleries which may score the sapwood (fig. 63). There is probably only one generation a year. The species is distributed throughout the Northwestern States from British Columbia southward in Oregon and eastward to Colorado.

Dryocoetes pseudotsugae Sw. is a secondary enemy of Douglas fir. The adults are reddish brown and are about three-sixteenths of an inch in length. They construct short, irregular galleries in the inner bark of wind-thrown and dying trees throughout California and northward to British Columbia. The young adults gather in galleries in the outer or inner bark, not in the cambium, to pass the winter. Emergence occurs early in the spring. Trees attacked in the spring produce mature beetles by August. There probably are one and a partial second generation each year.

Spruce Bark Beetles

Spruce trees are attacked by a large number of bark beetles, most of which are secondary enemies, breeding only in dying, felled, or weakened trees. A few species, however, such as the Englemann

spruce beetle, become exceedingly destructive at times. Young trees are sometimes killed by species of *Ips*, *Pseudohylesinus*, and *Dryocoetes*, and by other small engraver beetles.

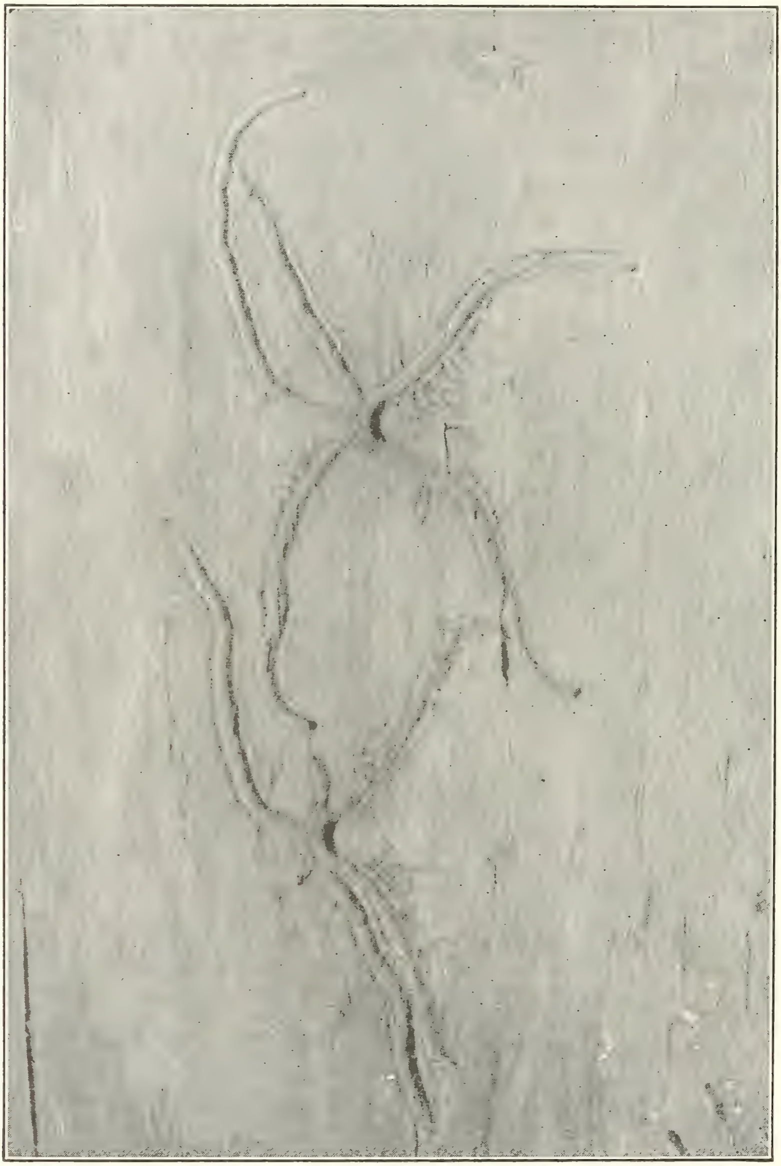

FIGURE 63.—Galleries of the western balsam bark beetle, *Dryocoetes confusus*.

The Englemann spruce beetle (*Dendroctonus englemanni* Hopk.) has caused widespread destruction of mature Englemann spruce in the Rocky Mountain region and is considered a very important

insect enemy of this tree. It will also attack other species of spruce within its range, which covers Oregon, Washington, Idaho, Montana, Wyoming, the Black Hills of South Dakota, Utah, Colorado, Arizona, and new Mexico. Large, overmature trees are preferred for attack, as are also trees weakened by mechanical injuries, logs, and windfalls. With large standing trees the base is seldom attacked, and examinations must be made at a height of 6 feet or more from the ground if the insects responsible for the injury are to be found.

The adult beetles are about one-fourth inch in length, reddish brown, with the body sparsely clothed with long hairs. They excavate a short, nearly straight, longitudinal egg gallery in the inner bark, slightly scoring the sapwood. The gallery is much wider than the beetles and is packed with boring dust, through which the adults keep a passageway open. Eggs are laid side by side in elongate cavities alternating from side to side of the egg gallery. The larvae at first bore out en masse, transversely from the egg gallery, but later make separate mines. The pupal cells are usually constructed in the inner bark, being exposed when the bark is removed, but are sometimes deeper in the bark, and quite concealed in thick-bark trees.

There is only one complete generation annually, but it shows considerable overlapping of broods. The winter is passed in all stages of development, except the pupal stage, with new adults predominating, in trees attacked the preceding summer. The overwintering adults emerge rather early in the season, but the emergence from the overwintering larvae is spread over a rather long period, owing to variations in individual development. The time of emergence and attack will vary materially, according to differences in elevation and exposure, but the period of heaviest attack is in June and July.

Since the developing larvae and pupae of this species are exposed when the infested bark is removed, such removal through peeling of infested trees will result in their destruction if the broods are in the larval or early pupal stage. The burning or severe scorching of infested logs is also an effective method of destroying the broods, especially when the beetles are in the adult stage. Owing to dense forest cover in most forests of Engelmann spruce the use of fire in beetle control will often be impractical because of the danger involved. As with the Douglas fir beetle, fall control is to be preferred to spring control.

The Alaska spruce beetle (*Dendroctonus borealis* Hopk.) attacks white and Engelmann spruce in Alaska and northwestern Canada. In appearance and habits it is very similar to the Engelmann spruce beetle, to which it is closely related.

The Sitka spruce beetle (*Dendroctonus obesus* Mann.) is usually considered as a secondary enemy of the Sitka spruce, but it has the potentiality of becoming destructive. At times it has killed a considerable volume of Sitka spruce along the coast of Oregon, Washington, and British Columbia.

Many species of small engraver beetles which breed in the dying bark of felled or weakened trees sometimes become so plentiful as to become dangerous to small spruce trees and the tops of older

trees. These belong to the same genera that are met with in pines and firs.

The Sitka spruce engraver (*Ips concinnus* Mann.) attacks the bark of living, dying, or felled Sitka spruce along the coast of Oregon and northward to Alaska. No reports have been received of its having done more than nominal damage. The adults are about one-eighth inch long, with three teeth, one very prominent and two smaller, on each side of the concave elytral declivity. They excavate an irregular central nuptial chamber, with three or four short curved or **S**-shaped galleries radiating therefrom. Four eggs are laid in each egg pocket and the four laval mines issuing from each pocket are a characteristic feature of its work. (See p. 111 for a general discussion of the work and habits of the *Ips* beetles.)

Other species of *Ips* which attack spruce include the following:

Species of *Ips*	Host and distribution
I. perturbatus Eichh	White spruce. Northern Canada and Alaska.
I. interpunctus Eichh	White spruce and Engelmann spruce. Alaska, Yukon, and British Columbia.
I. interruptus Mann	Sitka spruce, white spruce. Oregon to Alaska and eastward.
I. dubius Sw	Engelmann spruce. British Columbia and Rocky Mountain region.
I. tridens Mann	Engelmann spruce, Sitka spruce, and probably white spruce. Canadian Rockies and British Columbia.
I. engelmanni Sw	Engelmann spruce and white spruce in same region.
I. yohoensis Sw	Engelmann spruce and probably white spruce. British Columbia.

The Sitka spruce hylesinus (*Pseudohylesinus sitchensis* Sw.) is a small, densely scaly, suboval bark beetle which is found attacking felled or dying Sitka spruce in British Columbia, Washington, and Oregon.

Scierus annectens Lec., a small reddish-brown bark beetle about one-eighth inch long, attacks white spruce, Engelmann spruce, lodgepole pine, and probably Sitka spruce in western Canada and the Northwestern States.

Dryocoetes affaber Mann. attacks the tops of felled and dying Sitka spruce, Engelmann spruce, and Douglas fir from Alaska southward into the Northwestern States. The adults, which are less than one-eighth inch in length, construct irregular, short egg galleries.

Dryocoetes confusus Sw. (p. 125) may also be found attacking and sometimes killing Engelmann and other spruces.

Hemlock Bark Beetles

While hemlocks have a number of bark-beetle enemies, these are mostly of secondary importance, and seldom are any large number of trees killed.

Western hemlocks (*Tsuga heterophylla*) are sometimes attacked and killed by the Douglas fir beetle (p. 120) when associated with Douglas fir. At times weakened trees are attacked by species of *Scolytus* and *Pseudohylesinus*.

Mountain hemlocks, when in mixture with lodgepole pine, are sometimes killed by the mountain pine beetle (p. 102), but are most frequently attacked by a species of *Scolytus*.

The hemlock engraver (*Scolytus tsugae* Sw.) is a small, dark, shiny bark beetle about one-eighth inch in length, with the wing covers projecting over the concave abdomen. It constructs a short, straight egg tunnel across the grain, from one or both sides of a small entrance chamber. Both mountain and western hemlocks are attacked, and at times, as recently in Crater Lake National Park, the species is very destructive. It is distributed from British Columbia southward to California.

The hemlock hylesinus (*Pseudohylesinus tsugae* Sw.) is a stout, oval bark beetle about one-eighth inch long, reddish brown and sparsely clothed with scales and short stout hairs. It breeds prolifically in felled and dying western hemlock and also is known to attack and kill apparently healthy trees. It is reported from British Columbia and Washington, but will probably be found throughout the range of the host tree.

Bark Beetles Affecting Larch

Western larch is quite resistant to insect enemies, but it sometimes is killed by species of bark beetles that work in various other coniferous trees. Probably its most serious bark-beetle enemy is the Douglas fir beetle (p. 120). Dying and felled trees may be attacked by *Ips integer* or other small engraver beetles.

The larch engraver (*Scolytus laricis* Blkm.), which is very similar to *S. unispinosus* in appearance and habits (p. 122), has recently been described by Blackman from specimens found breeding in this tree.

Cedar Bark Beetles

All the closely related trees belonging to the families Taxodiaceae and Cupressaceae, such as the various cypresses, incense cedar, Port Orford cedar, Alaska cedar, western red cedar, redwood, and the various junipers, are attacked by diverse species of one genus of bark beetles, *Phloeosinus*. Not only is this genus practically confined to this group of trees (one species has been doubtfully recorded from pine), but as these trees have almost no other bark-beetle enemies, any species found working in the inner bark of cedarlike trees is almost certain to be a species of *Phloeosinus*. As a general rule these small oval beetles are not aggressive in their attack and are found working under the bark of trunks, tops, and limbs of weakened, dying, or felled trees, or of broken branches. Occasionally, however, they become sufficiently numerous and aggressive to attack and kill apparently healthy trees. Usually the greatest injury by these bark beetles is due to their habit, as newly emerged adults, of feeding on the twigs of healthy trees, often causing these to break or die. This habit is similar to that of most species of *Scolytus*. In constructing their brood burrows the beetles work in pairs, and, while there is some variation in the work pattern, the typical egg gallery consists of one short, longitudinal gallery arising from an enlarged entrance chamber, with the eggs very uniformly spaced along the sides and the larval mines extending laterally in a very regular pattern (fig. 64). Trees are attacked in the spring and summer, and there are one or one and one-half generations a year. The only method of artificial control is to fell

and burn the infested trees or severely scorch the bark. No control work has been attempted in the West except in California for the control of a species affecting ornamental Monterey cypress. Ap-

FIGURE 64.—Small redwood scored by galleries of the redwood bark beetle (*Phloeosinus sequoiae*) and a roundheaded borer (*Semanotus ligneus* var. *sequoiae*).

proximately 20 species have been described from western cedars and related trees. Many of these are rare and of little economic importance.

The western cedar bark beetle (*Phloeosinus punctatus* Lec.) attacks the trunk and larger limbs of western red cedar, incense cedar, Alaska cedar, and Port Orford cedar in the mountains of the Pacific Coast States and eastward through the range of western red cedar. It is a common species and at times quite injurious to living trees. The galleries consist of either one short tunnel, not over an inch in length, or two short tunnels in the form of a V. The beetles are dark red to black and about one-eighth inch long.

The juniper bark beetle (*Phloeosinus juniperi* Sw.) is dark brown and about one-eighth inch in length. It attacks the trunks of western juniper in California and Oregon. *P. scopulorum* Sw. breeds in *Juniperus scopulorum* in British Columbia and southward into Washington. *P. utahensis* Sw. breeds in *J. monosperma* in Colorado and Utah.

The redwood bark beetle (*Phloeosinus sequoiae* Hopk.) (*44*) is one-eighth inch long and the largest of the genus. It attacks weakened, felled, or fire-scorched redwood (fig. 64), western red cedar, and Port Orford cedar along the coast from British Columbia to central California.

The bigtree bark beetle (*Phloeosinus rubicundulus* Sw.) works in broken branches of big trees (*Sequoia washingtoniana*) in their native groves in California.

The cypress bark beetles, *Phloeosinus cupressi* Hopk. and *P. cristatus* Lec., are at times very destructive to the various species of cypress in California. Besides killing many trees outright, they mine and kill the twigs of ornamentals, making the trees very unsightly. The Sargent cypress bark beetle (*Phloeosinus variolatus* Bruck) is a large species which works in Sargent cypress in California. Other small species of cedar bark beetles which work mainly in twigs are discussed on page 32.

Bark Beetles Affecting Broadleaved Trees

Certain species and genera of bark beetles confine their attacks to various broadleaved forest trees. Some of these are important enemies of shade trees, park trees, and ornamentals. Some of the more common are mentioned in the following paragraphs:

The alder bark beetle (*Alniphagus aspericollis* Lec.) is a common, and often quite destructive enemy of western alders from British Columbia southward through California. The beetles usually attack weakened, dying, or felled trees. The adults are small, robust bark beetles about one-eighth inch long. They bore through the bark in pairs, usually at the base of branches, and construct a longitudinal egg gallery from 2 to 5 inches long, with no apparent nuptial cell. Eggs are placed close together along both walls of the gallery, with as many as 50 eggs to the inch. The larvae work out from the egg gallery and pupate in the soft inner bark. There appear to be two generations a year, with attacks occurring throughout the growing season.

The ash bark beetle (*Leperisinus californicus* Sw.) breeds in felled or dying ash trees in California and Oregon, and under certain conditions may be injurious to living trees. The adults are small bark beetles covered with scales. They construct egg galleries beneath the bark, with two transverse branches starting from a central en-

trance chamber. In the smaller limbs the galleries extend obliquely around the limbs and may completely encircle them. They are frequently very abundant in ash cordwood.

The oak bark beetles (*Pseudopityophthorus* spp.) in some instances attack so heavily as to cause the death of weakened oak trees. Usually, however, these beetles confine themselves to injured, felled, or recently killed trees or to the dead branches and twigs of otherwise healthy trees. The adults are tiny, cylindrical, brown bark beetles. Their typical work consists of transverse egg galleries extending for a short distance on either side of the central entrance tunnel and diverging larval mines running longitudinally with the trunk or limb.

The mountain mahogany bark beetle (*Renocis heterodoxus* Csy.) is a small brown bark beetle that mines the limbs and trunks of mountain mahogany in Oregon, Nevada, and California.

The shrub bark beetle (*Micracis hirtellus* Lec.) is a secondary species which mines the hard, dry wood of many flowering shrubs and broadleaved trees including willow, alder, and laurel in California. The adults are dark reddish brown and about one-eighth inch long. They have been found boring into lead telephone cables.

The birch bark beetle (*Dryocoetes betulae* Hopk.) is a secondary enemy of birch throughout British Columbia, Canada, and the northern part of the United States.

FLATHEADED BORERS

(Buprestidae)

The flatheaded or metallic wood borers (*12*) comprise a large family of beetles the larvae of which mine in the inner bark and wood of many species of forest trees. Their activities are diversified. A few species attack and kill healthy trees by mining under the bark; others bore into the inner bark and sapwood of trunks, branches, and twigs of weakened and dying trees; while others breed only in dead or recently felled trees and make flattened, winding wormholes through the wood. A few species are leaf miners. In general, the group is a destructive one in that they sometimes kill living trees and often reduce the value of lumber by their attacks. Others assist materially in the natural process of disintegrating deadwood in the forest, and these are decidedly beneficial.

The adults are flattened, frequently brightly colored beetles with a metallic luster. They fly and mate and then lay their eggs in bark crevices or on the outer surface of the bark, early in the spring or in summer. When the eggs hatch the young grubs construct long, winding, oval mines in either the bark or the wood, or in both (fig. 65). These mines gradually widen as the grubs increase in size and end in elongated, oval pupal cells. The slender white grubs are the stage usually found in trees, and they can be recognized by their long, legless bodies, shaped like a horseshoe nail. The head is small, and the first segment back of the head is much broader than the following body segments and has horny plates on the top and bottom. Growth of the larvae continues until fall, when activity ceases with the advent of cold weather. The winter usually is passed in the larval stage, although some larvae may pupate in the fall and pass

the winter as adults. Some species require 2 or even 3 or more years to complete their growth.

Since the beetles of this family have very diverse habits, only those species which attack and mine the inner bark of living trees will be considered in this section. Those species that work in the wood are more important from the standpoint of forest products and will be discussed in that section.

FIGURE 65.—Flatheaded borers (*Melanophila* sp.): *A*, Frass-packed channels in inner bark; *B*, full-grown larvae; *C*, adults; *B* and *C*, natural size.

For the control of flatheaded borers that mine in the inner bark, the same methods are used as for bark beetles. Infested trees usually are felled, peeled, and burned, and this work is frequently carried on in connection with the control of bark beetles.

The pine flatheaded borer (*Melanophila gentilis* Lec.) (*13*) is commonly found throughout the Western States, working beneath the bark of sugar pine, ponderosa pine, and Jeffrey pine. It is the species usually found infesting felled trees and logs, windfalls, and injured trees or occurring as a secondary species in the bole of standing trees. The adults are about one-half inch in length and are a bright, bluish green. The larvae are white, legless grubs about 1

inch in length. They are primarily bark-boring in habit and rarely enter the wood. On reaching maturity the larvae work out into the outer bark and pupate in oval cells close to the surface. There appears to be one generation annually.

The California melanophila (*Melanophila californica* Van D.) is similar in habits to the foregoing but has been found very destructive to various pines throughout California, Oregon, and Idaho. It is also reported from Douglas fir and bigcone spruce. Pines growing on rocky slopes, in fringe type stands, or in other situations where soil moisture is insufficient for normal tree growth, and old decadent trees are most frequently subject to attack. The larvae bore under the bark of the main trunk and scar the sapwood of apparently healthy trees, and it is the species of flatheaded borer most frequently found killing the tops of ponderosa pines. The adults are a greenish bronze and about one-half inch in length.

The fir flatheaded borer (*Melanophila drummondi* Kirby) is the species of this group most frequently found attacking Douglas fir, balsam firs, and hemlock. It also attacks western larch, spruce, and possibly other conifers. Though preferring trees that are dying or recently felled, the beetles sometimes attack and kill apparently healthy trees. The adults are from three-eighths to one-half inch in length and are metallic bronze or dull shining black and have an iridescent sheen. Some of the beetles have bright golden spots on the wing covers. *M. pini-edulis* Burke works in dying or dead piñon pine in Colorado, Utah, and Arizona.

Certain small, flat, nearly black metallic beetles called "firebugs" are well known to fire fighters in the pine region on account of their prevalence around forest fires, where they gather in large numbers on the men's backs or bite them on the neck, arms, and hands. They appear to be strongly attracted by the smoke of forest fires; and during conflagrations, owing to some peculiar instinct, they try frantically to lay their eggs on the still smouldering trees. Several species of *Melanophila* have this habit, the most common offenders being *M. acuminata* DeG. and *M. consputa* Lec., which attack badly fire-scorched or weakened pines, spruces, firs, and other conifers, and even some hardwoods. The larvae feed in the inner bark.

There are many other species of flatheaded borers that feed in and under the bark and do more or less damage to forest trees, but so far none of the western species have become of sufficient importance to require the application of control measures, and space does not permit listing them here.

ROUNDHEADED BORERS OR LONG-HORNED BEETLES

(Cerambycidae)

The roundheaded borers, or long-horned beetles (*24*), are an important group of forest insects, and include some very destructive species of tree-killing and wood-boring forms. Few of the western species, however, are serious enemies of living trees, although many species are injurious to forest products.

The adults are medium- to large-sized, oblong to cylindrical beetles, with antennae often longer than the entire body. These long antennae, or feelers, are their most characteristic feature and give them the

name of "long-horned beetles." The name "roundheaded borers" comes from the structure of the larvae, which are white, long, slender, usually legless grubs with enlarged thoracic segments, and with a horny plate on the top surface of the first segment near the head, but with no plate on the under side of this segment. This distinguishes them from the flatheaded larvae, which in most species have a plate both above and below.

While many of the species are characteristically wood-boring in habit, one group confines its work to boring beneath the bark. Some of these bark-boring species are injurious to living trees, whereas others work in the bark of trees killed by other insects, or breed in the bark of felled, fire-killed, or wind-thrown trees. Some are beneficial in that they feed so voraciously on the bark as to rob the primary bark beetles of their food and thus reduce their progeny.

The adults deposit their eggs in bark crevices, and the young larvae bore through the bark and construct long, irregular mines in the bark and wood. These are increased in size with the growth of the larvae and are usually packed with the bark or wood fibers of the larval borings.

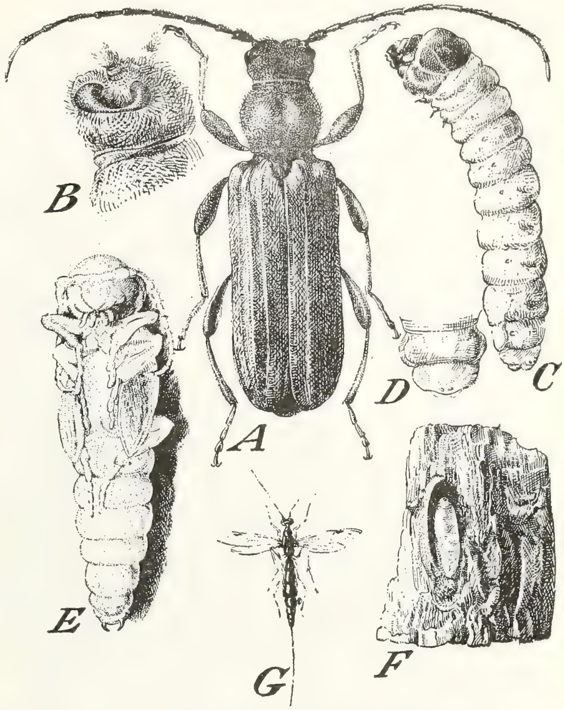

FIGURE 66.—Roundheaded fir borer (*Tetropium abietis*): *A*, Adult, × 3; *B*, detail of adult head, side view, × 4; *C*, larva, × 2; *D*, dorsal view of last abdominal segments of larvae × 2; *E*, pupa, × 2; *F*, cocoon of parasitized larva in pupal cell, natural size; *G*, Ichneumon parasite, natural size. (Drawing by Edmonston.)

So far no attempt has been made to control these species in western forests, and few are ever aggressive enough to warrant such measures.

The roundheaded fir borer (*Tetropium abietis* Fall) is probably the most injurious roundheaded bark-boring species in western coniferous trees. The grubs are commonly found working under the bark of felled balsam firs and are sometimes suspected of being responsible for the death of standing trees. In the adult stage this insect is a velvety brown beetle about three-fourths of an inch in length (fig. 66).

The western larch roundheaded borer (*Tetropium velutinum* Lec.) works between the bark and the wood of weakened larch and hem-

lock and is sometimes suspected of killing such trees. It is distributed through the Rocky Mountain and Pacific coast regions, where it also is found breeding in Douglas fir, balsam firs, and sometimes in pines. The adults are elongated, velvety brown beetles about one-half inch in length and are in flight from May to August. The larvae feed in the bark, where they construct irregular, winding mines which sometimes completely encircle the tree. During the later stages of larval development they may enter the wood to pupate, or pupate in the bark.

FIGURE 67.—Larva and work of the ponderosa pine bark borer (*Acanthocinus spectabilis*). The borings are shown crossing those of the western pine beetle. Insert: *A*, Male beetle; *B*, female beetle. All natural size.

The ponderosa pine bark borer (*Acanthocinus spectabilis* Lec.) (fig. 67), in the larval stage is the large white grub so commonly found in ponderosa pines killed by the western pine beetle, and is sometimes mistakenly supposed to be the insect responsible for the death of the trees. It also occurs in other pines. These insects are more beneficial than otherwise, in that they rob the bark beetles of their food. The adults are large, speckled, gray beetles with extremely long feelers, and the female has a long, hornlike ovipositor extending from the end of the abdomen.

The locust borer (*Cyllene robiniae* Forst.) (*22*, *34*, *45*) (fig. 68) is well known as an economically important insect pest of locust in the Eastern States and has spread as far west as Colorado and eastern Washington. The adults are somewhat slender, one-half to two-thirds of an inch in length, black, heavily marked with yellow, and with reddish legs. The markings on the wing covers or elytra consist of zigzagged and broken lines, and on the thorax and body are narrow yellow bands. The adults appear late in summer and lay their eggs in the crevices of the bark. The larvae bore irregular, winding galleries into the sapwood and heartwood of locust and

often bring about the death of the trees. Trees may harbor successive broods of these insects for a number of years before being killed. Much damage is caused by the wind breaking off the infested stems of young trees within 3 feet of the ground. The winter is passed by the very young larvae in the bark, and pupation occurs the following July. Damage in plantations can best be reduced by growing trees on good sites.

The poplar borer (*Saperda calcarata* Say) (*43*) breeds in felled and weakened aspen and poplar throughout most of the United States. The adults are elongate, robust, grayish beetles about 1 inch in length, with faint yellowish spots on the elytra, and the antennae are as long or longer than the body. Emergence of the adults occurs late in July and in August. The female chews a slit in the bark, in which one or two eggs are deposited. The young larvae mine into the bark and remain there over winter. They enter the sapwood and heartwood the following spring, where they feed for 2 years. During this time an opening is maintained through the bark where the eggs were laid, and through this boring dust is expelled. When mature the larvae construct pupal cells near the lower end of the larval mines, and in these they remain inactive until the following spring. In July of the third year the adults emerge through the holes used by the larvae for expelling frass.

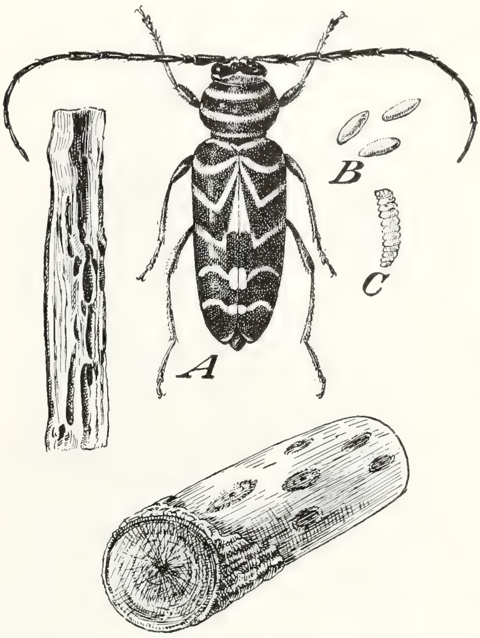

FIGURE 68.—Locust borer (*Cyllene robiniae*): *A*, Adult, × 2.5; *B*, eggs, × 2.5; *C*, larva, one-half natural size. (Drawing by Edmonston.)

The amethyst cedar borer, (*Hylotrupes*) *Hemicallidium amethystinum* Lec., attacks western red cedar, incense cedar, and juniper; and although it usually selects injured or dying trees, it sometimes appears responsible for killing healthy trees. The adults are black, over 1 inch in length, and have violet or bright-blue wing covers.

Other species of bark-boring roundheaded beetles are as follows:

Species	Hosts and distribution
Atimia dorsalis Lec	Cypress, juniper, and incense cedar. Western States.
Semanotus ligneus F. var	Juniper, cedar, big tree, redwood, hemlock, spruce, Douglas fir, balsam firs, larch, cypress, and pines. North America.
Phymatodes nitidus Lec	Cypress, redwood, and cedar. Pacific coast.
Leptostylus nebulosus Horn	Balsam firs. Oregon.
Acanthocinus obliquus Lec	Pines and spruce. Western States.
Phymatodes decussatus Lec	Oak. Washington.

BARK WEEVILS

Some bark weevils of the genus *Pissodes* (*48*) are particularly important as enemies of terminal shoots (p. 33); others attack the basal portion of the trunk of small trees and may extend their work into the roots. Weakened, suppressed, and decadent trees are usually preferred, but under some conditions these insects may attack healthy trees. Usually they breed under the bark of logs, in stumps, or under the bark of dying, standing trees and hence are of little economic importance.

FIGURE 69.—Yosemite bark weevil (*Pissodes yosemite* Hopk.) Typical work and adults. Natural size.

The adults are stout beetles with uniform or variegated markings of yellow, brown, or black. The head is prolonged into a snout or break, which is used to puncture buds and tender bark of terminal or lateral branches for feeding purposes, and in the case of the female to make a hole for the reception of the eggs. The larvae are small, white, legless grubs, with curved cylindrical bodies. The larvae mine under the bark and form winding galleries, gradually increasing in size, which extend through the inner bark and sometimes score the sapwood. Each mine ends in a pupal cell constructed partly in the bark but mostly in the sapwood. This cell is oval in outline and is lined with excelsiorlike shreds of wood fiber. The nearly round larval mines and the "chip cocoons" are characteristic features of their work.

The adults are long lived and may deposit their eggs over a considerable period of time. The larvae, which reach maturity rapidly, usually within 2 or 3 months, may overwinter in the galleries or transform to adults that either overwinter under the bark or emerge and hibernate in the ground. There usually is but one generation annually.

Artificial control of the species in western forests has never been found necessary, as they are usually held in check by natural enemies and the limitation of suitable breeding material.

Bark weevils of the genus *Pissodes* that are most commonly found breeding under the thick bark at the base of small conifers, and the hosts in which they breed are as follows:

Species of *Pissodes*	Hosts and distribution
P. yosemite Hopk. (fig. 69)	Ponderosa pine, sugar pine, and western white pine. California, Oregon, and Washington.
P. californicus Hopk	Ponderosa pine. California.
P. webbi Hopk	Ponderosa pine, Mexican white pine, and lodgepole pine. Southern Rocky Mountains.
P. radiatae Hopk	Monterey pine, Bishop pine, knobcone pine, and lodgepole pine. California and Washington.
P. murrayanae Hopk	Lodgepole pine. Eastern Oregon, Washington, and the northern Rocky Mountain region.
P. curriei Hopk	Western white pine. Northern Rocky Mountains and northward into Canada.
P. fasciatus Lec	Douglas fir. Oregon, Washington, Idaho, and British Columbia.
P. piperi Hopk	Balsam firs. Oregon, Washington, Idaho, and British Columbia.
P. burkei Hopk	Alpine fir. Rocky Mountains.
P. costatus Mannh	Sitka spruce. Oregon to Alaska.
P. coloradensis Hopk	Spruces and western white pine. Rocky Mountains.
P. alascensis Hopk	Engelmann spruce and probably other spruces. Montana and northward into Alaska.

(Also see terminal-feeding *Pissodes*, p. 33.)

PITCH MOTHS

There are several species of moths, belonging to different families, that attack the bole and larger limbs of living forest trees. Eggs are laid on wounds or on the bark surface, and the caterpillars which hatch therefrom mine into the inner bark and feed upon the exudation of pitch. These larval galleries are filled with a thick, gummy pitch, and a large mass of pitch accumulates on the outside of the bark at the point of attack. Because of the character of their work they are called pitch moths. Some species are very injurious to the tops of trees, but the majority simply extend local wounds and do not threaten the life of the trees.

One large group of these pitch moths belongs to the family Aegeriidae, called clear-winged moths owing to the absence of scales on the wings and the general resemblance to wasps.

The sequoia pitch moth (*Vespamima sequoia* (Hy. Edw.)) (*7*) attacks various coniferous trees throughout the Western States, including pine, Douglas fir, and redwood. Although the caterpillars of this moth are frequently found working in large pitchy masses on wounds of forest trees, the species is not a serious enemy. Sometimes breakage follows the attacks on small trees, or the pitchy, healed-over galleries cause defects in the lumber.

The adults are clear-winged moths about two-thirds of an inch in length, somewhat resembling a wasp or yellow jacket, as the body is marked with yellow lines. The caterpillars are dirty white or yellowish and about three-fourths of an inch long when full grown.

The adults appear in the latter part of June and in July and lay eggs in bark crevices or in mechanical wounds on the trees. The larvae start the construction of mines from the place where the eggs are laid and bore winding mines through the inner bark and the outer layers of wood. A large mass of gummy, sticky pitch, mixed with boring dust, exudes from the point of entrance.

Two years are required to complete the life cycle, and both winters are passed by the larvae in their galleries. When mature the larvae transform to pupae within the pitch mass, and just prior to emergence the pupae push their way partially out so as to permit the moths to emerge without coming in contact with the pitch mass.

The Douglas fir pitch moth (*Aegeria novaroensis* Hy. Edw.) (*8*) attacks Douglas fir throughout the range of this tree and has also been recorded from weakened larch. As in the case of the sequoia pitch moth, its economic importance lies primarily in the subsequent lumber defects.

The adults are clear-winged moths with a wing expanse of 1¼ inches. They have spots of orange red on the thorax and bands of the same color on all the body segments except the last. The males are distinctly smaller than the females. The larvae are slender white caterpillars with brown heads, and when full grown range in length from 1 to 1½ inches. The larval skin is quite transparent, and in this respect the larvae differ from those of the sequoia pitch moth.

Brunner reports the appearance of the adults during the latter part of May and in June. The habits are comparable to those of the sequoia pitch moth, except that 4 years are required for development. Winters are passed by the larvae in their galleries, which are covered with large accumulations of pitch.

The spruce pitch moth (*Parharmonia piceae* Dyar) is a shining black species with a red spot on the under side of the abdomen. The caterpillars work in Sitka spruce along the coast of Oregon and Washington.

There are many other species of clear-winged pitch moths that work in various coniferous and broadleaved forest trees, though they are rarely found and are of little economic importance. Some of the species of the family Pyralidae, or snout moths, work in the inner bark of various coniferous trees, causing a heavy exudation of pitch, and cause injury very similar to that of the clear-winged moths. Most of these do more serious damage to young trees than to older ones and therefore were discussed in the section dealing with younger trees (p. 37).

Many species of clearwing moths or pitch moths belonging to the family Aegeriidae work in the inner bark and bore into the wood of various forest trees. An exceptionally large number of these work in the wood of broadleaved trees and at times so riddle the interior that the limb or tree dies or is broken off by the wind, and the products derived from the wood show serious injuries. The adults of this group are very pretty moths with clear wings, and resemble hornets. The caterpillars are naked or have only a few prominent hairs. There are so many species that are seldom seen by the forester that no attempt will be made to list the western species here. The alder borer (*Aegeria americana* Beut.) is sometimes found working in alder. The locust clearwing (*Paranthrene robiniae* Hy. Edw.) is sometimes very injurious to locust and poplar. The cottonwood crown borer (*Aegeria tibialis* Harr.) infests poplar and willow, as does also *A. pacifica* Hy. Edw. and *Alcathoe apiformis* Clerck. *Aegeria mellinipennis* Bdv. attacks sycamore and oak in California.

INSECTS INJURIOUS TO WOOD AND FOREST PRODUCTS

Insects lay a heavy toll on crude and finished forest products (*26*, *47*, *72*, *76*), a loss that has been variously estimated to be from 1 to 5 percent of the annual cut. The principal damage to forest products is caused by insects that feed on or bore into the wood. Some damage is done to wood while still in living trees, but a great deal occurs after trees have been killed or felled, and before utilization; and the green or seasoned lumber, and even the final utilized products are fed on by insects.

After a tree has been killed by fire, insects, or other causes, or felled by wind, snow, or cutting operations, it becomes particularly attractive to a large variety of insects. Ambrosia beetles find the dying wood with fermenting sap an especially suitable medium for the growth of their fungi. Horntail wasps, or wood wasps, settle on freshly felled trees, sometimes before the woodsmen have finished cutting them into logs, and on fire-killed trees before the fire is out, and insert their long slender ovipositors deeply into the wood to lay their eggs. Many of the flatheaded and roundheaded borers, weevils, and larvae of carpenter moths and clear-winged moths are wood boring in habit. The larvae usually feed for a time in the cambium layer and then penetrate the wood. Fresh, unseasoned wood still containing sap, pitch, or other essential food elements is required for them. In short, so many different species of wood-boring insects start their work on killed or felled trees that it is important that such timber be peeled or promptly removed from the woods to avoid heavy damage.

After lumber has been kiln dried it becomes reasonably safe from insect attack. There are, however, a few important groups which still persist in their attacks unless the wood is properly handled. The seasoned sapwood of hardwoods is particularly susceptible to damage by powder-post beetles and must be carefully managed in the lumber yard or in storage to avoid becoming infested. Even after timbers are in place they are subject to attack by these insects, by carpenter ants, by certain roundheaded wood borers, flatheaded borers, and by termites unless precautions are taken to provide proper insulation from the ground or protection is secured through the impregnation of the wood with creosote or other chemicals.

As has been indicated, the control of insects injurious to forest products is largely a matter of prevention of damage through cutting at the proper season, prompt removal of logs, poles, and stulls from the woods, proper handling in the mills, and certain precautions in utilization. Logs that are to be used for poles or in rustic work should be peeled before wood borers have had an opportunity to enter the wood. Some success has been obtained in repelling attacks of wood borers by spraying logs with coal-tar creosote diluted with 3 parts of kerosene (*23*). In cases where logs have been attacked, the insects can be killed by spraying with crude orthodichlorobenzene at full strength or paradichlorobenzene dissolved in 3 parts, by weight, of kerosene (*72*). All such treatments, however, give only a temporary immunity. More specific methods are discussed for each of the different insect groups.

KEY TO DIAGNOSIS OF INSECT INJURY TO WOOD AND WOOD PRODUCTS

A. Insects attacking green, unseasoned, or seasoning wood, living or dying trees, or freshly felled trees or logs, and projecting their tunnels directly into and through the wood.

1. Small, circular, open pinholes, often surrounded by dark stains; diameter uniform and less than one-eighth inch; made by small, brown, shining, cylindrical beetles______________________________ ambrosia beetles, page 143.
2. Large, more or less circular holes in wood; diameter more than one-eighth inch; lightly filled with pellets; wood stained or not.
    - *a.* Nearly circular holes of medium size in wood of broad-leaved trees made by caterpillers clear-wing moths, page 139.
    - *b.* Very large irregular holes one-half to 1 inch in diameter in broadleaved trees, usually lined with a silky yellowish-brown web__ carpenter moths, page 154.
3. Circular, oval, or irregularly shaped tunnels of varying width gradually increasing to more than one-eighth inch in size; usually tightly packed with fine boring dust or coarse frass, except at ends occupied by larvae or pupae.
    - *a.* Tunnels flatly oval, usually lightly packed with arc-like layers of sawdust-like borings and pellets of woody excrement, and surface of wood marked by fine, transverse, crescentric lines; made by slender, white, legless grubs shaped like horseshoe nails with very wide, flat segments back of head; first segment with a well developed plate on both upper and lower surfaces, upper plate marked with a central line, groove, V or Y flatheaded borers, page 147.
    - *b.* Tunnels broadly oval to nearly circular, tightly packed with sawdustlike borings and pellets of wood excrement; made by long, thick, white, apparently legless grubs, with horny plate on top of first thoracic segment, which is somewhat enlarged roundheaded borers, page 150.
    - *c.* Perfectly circular holes in wood, not evident in cambium, made by long, white, cylindrical grubs with small heads, fleshy lobes for thoracic legs, and the abdomen terminating rearwards with a sharp horny prong__ horntails and certain Coleoptera, page 155.

B. Insects attacking living trees and causing black checks, pitch pockets, pitch flecks, gum spots, or ring distortion, but not causing pinholes or wormholes.

1. Black checks showing in wood of conifers, surrounded by curled or distorted wood________________ bark maggots, page 158.
2. Birdseye pitch flecks in pine________________ pitch midges, page 54.
3. Double rings, distorted rings, retarded growth [7]_ defoliators, page 58.
4. Pitch pockets, gum spots, and pitch streaks in coniferous woods_________________________________ bark beetles, page 96.
    ____________________________ flatheaded borers, page 132.
    _________________________________ pitch moths, page 139.
    _______________________ terminal-feeding insects, page 29.

C. Insects attacking sawed lumber, seasoned wood, or utilized wood products.

1. Small wormholes in wood, tightly packed with a very fine powder, powder sometimes pushed out through holes in wood. Usually working in very dry wood.
    - *a.* Small, nearly round tunnels in various hardwoods powder-post beetles, page 159.
    - *b.* Irregularly shaped tunnels in softwoods and hardwoods (see above under A, 3).

[7] Also from causes other than insects.

2. Large cavities, lightly filled with excrement pellets or frass, not tightly packed with boring dust. Insects working in either dry or moist wood.
   a. Made by big black ants which leave only chewed wood fibers in cavities or push these out of the tunnels, leaving the same quite clean
   carpenter ants, page 161.
   b. Made by soft, antlike insects with white bodies and brown heads which usually leave many oblong impressed excrement pellets____________ termites, page 162.

INSECTS WORKING IN UNSEASONED LOGS OR LUMBER

THE AMBROSIA BEETLES OR PINHOLE BORERS

Ambrosia beetles (*52*) are important enemies of forest products because of their ability to riddle the sapwood and even the heartwood of unseasoned logs or poles with small round pinholes or shot holes. These holes become surrounded with a dark-brown or black stain. The beetles of this destructive group belong to the families Scolytidae and Platypodidae, and although related to the bark beetles, they have very distinctive habits.

The adults are small, reddish-brown to nearly black, cylindrical beetles that select for their attack dying or freshly felled trees, sawlogs, green lumber, or other unseasoned or moist wood such as stave bolts, or wine, beer, or vinegar casks. Small round tunnels are bored directly into the sapwood or heartwood, and since the beetles do not feed on the wood the borings are cast out of the tunnels and collect on the surface of the bark or wood as a fine light-colored powder. The character of the tunnels varies with different species. Some construct an open, simple cavity; others a long, winding, circular gallery; while still others construct what is called a compound tunnel in that small pockets or larval cradles are gnawed along the main channel. Into the tunnels, either intentionally or not, the adults carry the spores of certain fungi. These become detached, and, if moisture conditions are suitable, the fungi begin to grow along the walls of the galleries. Each species of beetle has its own specific ambrosial fungus, and the selection of trees for attack probably depends largely upon the requirements of the fungi. Some beetles specialize on certain species of trees, while others are more general in their attacks. As the fungi grow they are fed upon by the beetles and the developing larvae. The living requirements of these insects are very exacting. If moisture conditions are not suitable the fungi fail to grow, and the beetles starve, or if the fungi grow too abundantly, the beetles are unable to cope with them and are smothered in their own food. For this reason only moist, unseasoned wood is suitable for attack, and dried seasoned lumber is immune.

The shot holes and the accompanying stain are serious defects of lumber and often render it worthless. In some seasons 30 percent or more of the lumber from Douglas fir logs on the Pacific coast has been ruined by the attacks of these beetles. Spruce airplane stock has been badly damaged in this same region. Damage is usually the greatest in the South or along the coast where mild winters give favorable temperature and moisture conditions for a long period of beetle activity. Where the winters are severe the

beetles become inactive and thus a longer period may elapse between the time of cutting and the removal of logs, before damage becomes important.

The control of ambrosia beetles is largely a matter of prevention of damage through the regulation of woods practice and proper handling of the products from the mill. Logs cut in the summer or fall should be removed from the woods within a week or two after cutting and either placed in water or run through the mill (*56a*). Logs cut late in the fall, in widwinter, or early in the spring will be reasonably safe until the approach of warm weather but often

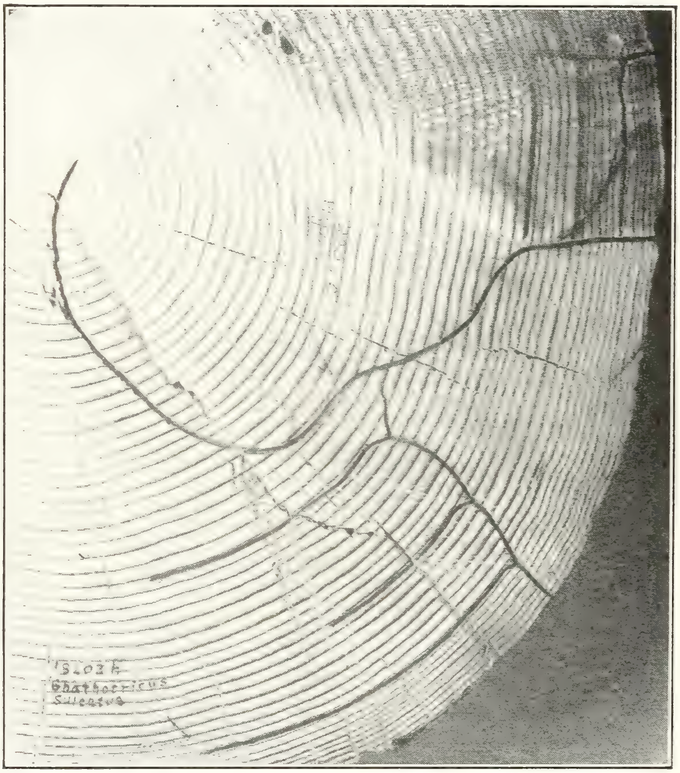

FIGURE 70.—Tunnels in fir made by ambrosia beetles: Long winding tunnel made by *Platypus wilsoni*; branching tunnels made by *Gnathotrichus sulcatus*.

cannot be removed before damage has occurred. Freshly sawed lumber will be safe from attack if it is dried quickly, but some damage may occur in storage if the lumber is piled so as to remain or become moist. Logs or wood either heavily soaked with water or quite dry are not suitable for attack, but the exposed parts of logs left floating in ponds are very apt to become infested. In general, the control of these beetles is very difficult, and prompt utilization or kiln drying of the lumber is about the only satisfactory solution (*49c*). A small amount of parasitism has been noted

in studies connected with the work of these beetles in seasoned products, but it is of insufficient importance to reduce appreciably the number of beetles and the injury they cause.

Wilson's wide-headed ambrosia beetle (*Platypus wilsoni* Sw.) is very different from the other species in that the adults are long, slender, somewhat flattened, reddish-brown, shining beetles about one-fourth inch in length, with a few long yellow hairs, projecting wing covers, and broad heads. They construct round, winding tunnels, of a few inches to a foot in length (fig. 70), into the sapwood and heartwood of dying, weakened, injured, or recently dead or felled balsam firs, Douglas fir, spruce, and hemlock, and sometimes other conifers. At intervals along the main tunnel secondary tunnels branch horizontally. Eggs are deposited loosely in small clusters in the tunnels, each female laying 100 or more. The young larvae wander freely about in the mines, feeding on the ambrosial fungus, and reach maturity in 5 or 6 weeks. When full grown they excavate cells at right angles to the main gallery in which to transform to pupae and adults. These cells are parallel to the grain of the wood and are often arranged in groups of 8 to 10 or more. The insect is distributed over the entire Pacific Northwest, where it is the only representative of the family Platypodidae.

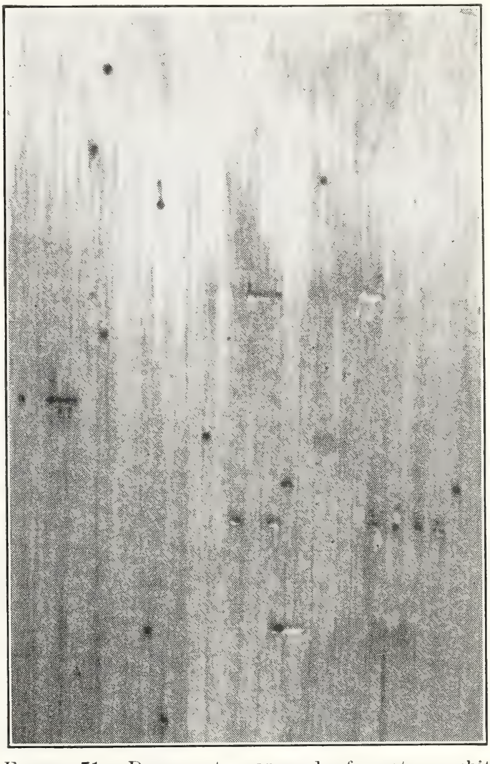

FIGURE 71.—Damage to sapwood of western white pine log caused by an ambrosia beetle (*Trypodendron sp.*).

The wood stainers of the genus *Gnathotrichus* are small, cylindrical, dark-brown or black beetles of the size and appearance of a short piece of pencil lead. They attack nearly all species of conifers in the Western States, and one species works in alder. Their work is distinguishable from that of other western ambrosia beetles in that a primary tunnel penetrates the sapwood, and at intervals along this tunnel secondary tunnels branch horizontally, the branches more or less following the annual rings. The tunnels are of the compound type, in that larval cradles are constructed at regular intervals, both above and below the primary and secondary galleries. The species so far recorded in the West are as follows:

Species of *Gnathotrichus*	Hosts and distribution
G. retusus Lec	Pines, hemlock, Douglas fir, and balsam firs. Western States and Canada.
G. sulcatus Lec	Spruce, hemlock, Douglas fir, and balsam firs, and sometimes also pines, redwood, cedar, and other conifers. Western States.
G. aciculatus Blkm	Ponderosa pine, Mexican white pine, Douglas fir, and white fir. Rocky Mountain region.
G. denticulatus Blkm	Pines and white fir. New Mexico, Arizona, and Texas.
G. alni Blkm	Alder. Western Oregon and Washington.

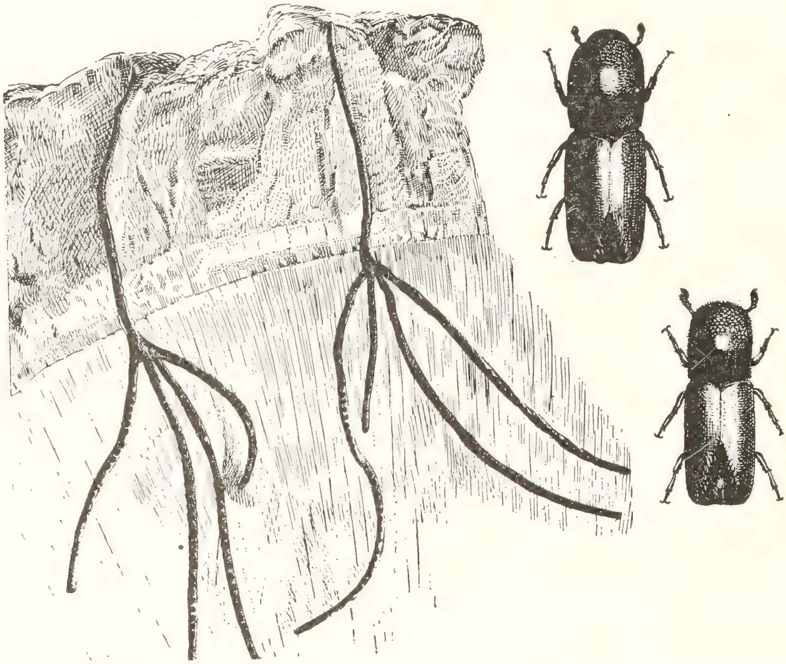

FIGURE 72.—Tunnels of the oak timber beetle (*Pterocyclon scutellare*) and adults: Male above, female below, × 8.

The ambrosia beetles of the genus *Trypodendron* are small, stubby, dark-colored beetles, with a roundish prothorax and a smooth, more or less shining body, often with lighter colored longitudinal stripes. They attack the wood of many species of coniferous and broad-leaved trees and are distributed throughout the greater part of the United States and Canada. Their galleries (fig. 71) are of the compound type with larval cradles arranged in series both above and below the main tunnels, which branch in a horizontal plane and cut across the grain of the wood.

The species most frequently encountered in the Western States are as follows:

Species of *Trypodendron*	Hosts and distribution
T. bivittatum Kirby	Nearly all conifers. North America.
T. rufitarsis Kirby	Lodgepole pine. Idaho, Montana, Oregon, and Washington.
T. cavifrons Mann	Pine, spruce, alder, birch, and cedar. Pacific Northwest.

Species of *Trypodendron*	Hosts and distribution
T. borealis Sw	Engelmann spruce and white-bark pine. Idaho and Montana.
T. ponderosae Sw	Ponderosa pine, Engelmann spruce, Douglas fir, and mountain hemlock. British Columbia and south to Oregon.
T. retusus Lec	Poplar and aspen. Western States and Canada.

The oak timber beetles of the genus *Pterocyclon* (*Monarthrum*) are small, elongate, cylindrical, dark-brown ambrosia beetles which work in the wood of oak and various other hardwoods and deciduous trees. After the beetles have entered into the wood they excavate a central nuptial chamber from which secondary tunnels branch in three or four directions. From the secondary branches the larval cradles are excavated at right angles and parallel to the grain of the wood. *Pterocyclon scutellare* Lec. (fig. 72), about one-eighth inch in length, works in various species of oak from Oregon to southern California. *P. dentiger* Lec. is a smaller species, about one-sixteenth inch in length, which works in the same trees in California.

Species of *Xyleborus* make very small pinholes in the dying or dead wood of a wide assortment of fruit, shade, and forest trees. Larval cradles are not formed, and the tunnels are either plain or enlarged into cavities where the larvae feed. Most frequently their work is found in dying or recently dead wood. *Xyleborus scopulorum* Hopk. works in the dead wood of ponderosa pine and Coulter pine in California, Oregon, and South Dakota. *X. arbuti* Hopk. works in madroña in California. *X. xylographus* Say is the very common eastern species which attacks a large variety of hardwoods. Similar species in the Western States have been referred to this species. The galleries consist of simple branching tunnels in which the larvae live and feed upon ambrosial fungus without constructing an enlarged cavity or larval cradle.

THE FLATHEADED WOOD BORERS

(Buprestidae)

The flatheaded borers have been previously discussed under the section on cambium or inner-bark miners (p. 132). By far the larger number of species, however, are of more economic importance as wood borers than as killers of living trees. Many species work first in the inner bark of dying trees, then extend their tunnels into the sapwood and even into the heartwood. The flattened oval wormholes that are made by the horseshoe-nail-shaped grubs are usually tightly packed with boring dust and may wind in a tortuous fashion back and forth through the wood so as to riddle it completely. Even a few such wormholes greatly lower the quality of the lumber, and a large number make it unfit for any but the roughest use. Some of these wood borers attack the pitchy fire scars on living trees and gradually extend their mines into the sounder portions. Many others attack trees that have been killed or felled and do most of their damage while the wood is still unseasoned. Others will attack wood after it has been run through the mill and is placed in storage, or even after it has been put into use.

The prevention of fire scars and other injuries to standing trees and the prompt utilization of dead or felled trees will reduce this

damage to a low point. In wood that has become infested after being put into place, the grubs usually can be reached and killed by liberal applications of crude orthodichlorobenzene or kerosene.

The sculptured pine borer (*Chalcophora angulicollis* Lec.) (fig. 73) is the largest of the western species of flatheaded borers and the only western representative of this genus. The adults are over 1 inch long and dark brown to black, with an iridescent bronze luster, especially on the under side. The upper surface is marked with irregularly sculptured areas. Many a woodsman has been startled on a warm summer day to have one of these large beetles suddenly take flight with the noise of a small airplane from its quiet resting place on a nearby tree trunk. The larvae feed in the wood of dead pines and firs throughout the Western States.

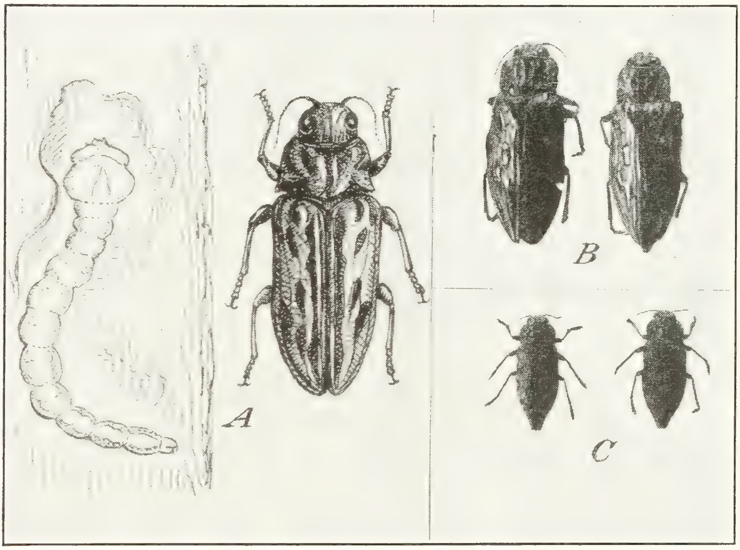

FIGURE 73.—Flatheaded wood borers: *A, Chalcophora angulicollis,* larva and adult, × 1.5 (drawing by Edmonston); *B,* the same, natural size; *C, Dicerca tenebrosa,* natural size.

The golden buprestid (*Buprestis aurulenta* L.) is one of the most destructive species in this group. The adults are beautifully colored beetles one-half to three-fourths of an inch in length, with a flattened oval body and an iridescent green or bluish color, with all margins bordered with copper. They are particularly attracted to pitchy wood and lay their eggs on fire scars or the exposed pitchy wood of pines, firs, and other conifers. Flooring and woodwork of Douglas fir that is not heavily covered with paint or varnish is sometimes repeatedly attacked until the interior is completely riddled and destroyed. If the wood is very dry, it takes several years for the larvae to complete their development.

There are about 12 other species in this genus of highly colored beetles that do similar damage to the wood of western forest trees. Some of the more common are as follows:

Species of *Buprestis*	Hosts and distribution
B. adjecta Lec.	Jeffrey, lodgepole, and other pines. Western States.
B. connexa Horn	Jeffrey pine and ponderosa pine. California, Oregon, Idaho, and Montana.
B. laeviventris Lec.	Ponderosa pine and other pines and Douglas fir. California, Oregon, Washington, Idaho, and Arizona.
B. maculativentris var. *subornata* Lec.	Pines. Western States.
B. rusticorum Kirby	Douglas fir and balsam firs. Throughout the Western States.
B. langi Mann	Douglas fir and ponderosa pine. All Western States.
B. viridisuturalis N. and W.	Poplar, cottonwood, and white alder. California and Oregon.
B. confluenta Say	Poplar and aspen. Throughout the United States.
B. gibbsi Lec.	Oak and cottonwood. California, Oregon, Washington, and Colorado.

The dicerca beetles, members of the genus *Dicerca*, are medium-sized, robust, roughly sculptured, metallic, wood-boring beetles of a dull bronze color, with the tips of the wing covers prolonged into narrow points. The larvae work under the bark and into the wood of various species of trees that are sickly, dying, or dead. Of the 10 species recorded from the Western States, those most frequently found breeding in the wood of forest trees are the following:

Species of *Dicerca*	Hosts and distribution
D. tenebrosa Kirby (fig. 73)	Pines, balsam firs, Douglas fir, and Engelmann spruce. California, Oregon, Washington, Idaho, Montana, and Eastern States.
D. sexualis Crotch	Douglas fir, ponderosa pine, Jeffrey pine, and knobcone pine. New Mexico, Arizona, California, Oregon, and Washington.
D. crassicollis Lec.	Lodgepole pine and Douglas fir. California, Oregon, Washington, and Idaho.
D. prolongata Lec.	Aspen, cottonwood, poplars, alder, and other broadleaved trees. All Western States.
D. horni Crotch	Alder, madroña, oak, sycamore, and other broadleaved trees and shrubs. Montana, Idaho, Washington, Oregon, and California.
D. divaricata Say	Alder, birch, and other broadleaved trees. Colorado.

The western cedar borer (*Trachykele blondeli* Mars.) (*14*) (*49a*) mines in the sapwood and heartwood of living, injured, dying, or dead trees of western red cedar, cypress, and related species and is very destructive to trees used for poles, shingles, cooperage, shipbuilding, or other purposes where sound wood is required. The adults, which are roughly sculptured beetles about five-eighths of an inch in length, of a very beautiful, bright emerald green with a golden sheen, lay their eggs on the wood of scars on the trunk or branches of standing trees, and the flatheaded larvae mine about in the wood for a period of 2 or 3 years before reaching maturity. The newly formed beetles remain in the wood for about 6 months, from September to May, before they emerge and start a new generation. There is no practical means of control under present forest conditions. The variety *T. blondeli juniperi* Burke is found in junipers in California.

Three other species of this genus are found in the Western States doing similar work in various cedarlike trees.

Species of *Trachykele*	Hosts and distribution
T. opulenta Fall	Incense cedar, big tree, western red cedar, and related trees. California, Oregon, and Washington.
T. nimbosa Fall	Balsam firs and mountain hemlock. California, Oregon, Washington, Idaho, and British Columbia.
T. hartmani Burke	Sargent cypress. California.

Below are listed other western species of wood-boring buprestids that may cause damage of some economic importance:

Species	Hosts
Poecilonota spp	About 5 species which breed in willows and poplars.
Chrysobothris spp	About 26 species in both conifers and broadleaved trees.
Acmacodera spp	About 18 species in various broadleaved trees and shrubs.
Polycesta spp	Three species in broadleaved trees and shrubs.

(Also see bark-, twig-, or cone-bearing buprestids, pp. 21, 35, 132.)

THE ROUNDHEADED WOOD BORERS

(Cerambycidae)

The roundheaded borers or long-horned beetles (*21*) have been previously discussed (p. 134) under the section of miners of the inner bark and cambium region. The western members of this family, however, are much more important from the standpoint of damage to forest products than in the role of killers of living trees. Most of the species are typically cambium-wood insects, in that the larvae first mine in the cambium region of dying or dead trees and then extend their tunnels into the sapwood and in some cases into the heartwood. The large, broadly oval wormholes are a serious defect in lumber, and if these are numerous the wood becomes worthless for lumber purposes. Dying or dead trees, those killed by insects or fire, or trees felled in cutting or by windstorms are most frequently selected for attack; and if such timber is not promptly removed from the woods, it may soon be completely ruined for commercial purposes. The salvage of fire-killed trees frequently depends upon the rapidity with which they can be removed from the danger of attack by these borers. Unpeeled logs left in the woods during certain seasons of the year are often seriously damaged.

There is no way in which these insects can be controlled in the woods, and there seems little likelihood that practical methods will be developed that will prevent attack on dead or dying trees or recently felled logs. As with other insects that attack unseasoned wood, about the only thing that can be done is to remove the logs from the woods as quickly as possible and place them in water or run them through the mill and kiln-drying process. A few of these insects, however, are of importance even after the lumber is placed in storage.

The ponderous borer (*Ergates spiculatus* Lec.) is very destructive to the wood of recently killed or felled coniferous trees, to fallen logs and stumps, and even to power and telephone poles. Recently it has been found to be a most important determining factor in the salvage of fire-killed Douglas fir. The heartwood of this tree is very resistant to deterioration until penetrated by the large mines of this wood-boring species. The adults are the largest of our western beetles, measuring from 1½ to 2¼ inches in length (fig. 74).

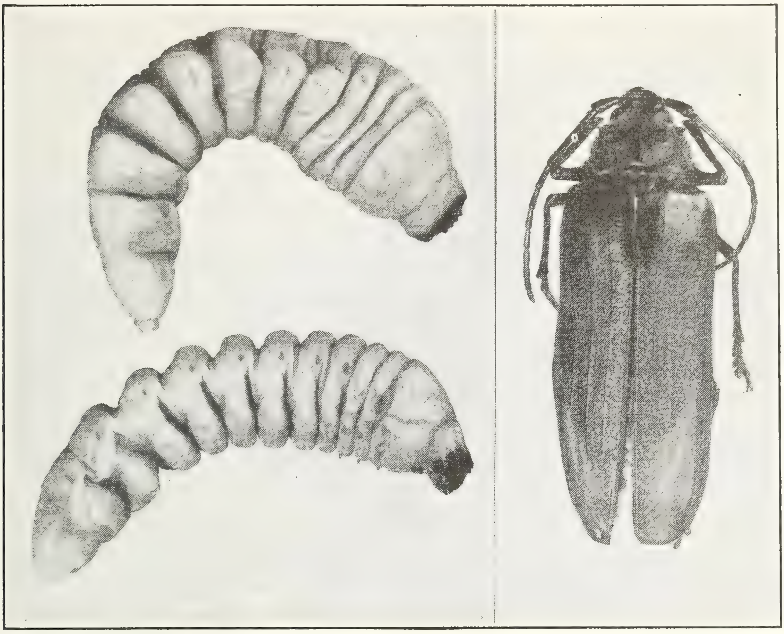

FIGURE 74.—Larvae and adult of the ponderous borer (*Ergates spiculatus*). Natural size.

The color is uniformly dark brown, with the head and thorax somewhat darker than the elytra. The sides of the prothorax are armed with a few large or many small teeth or spines. They are often found flying around lights early in the summer. Eggs usually are laid in crevices of the bark of dead trees or stumps, and the larvae excavate large channels, packed with coarsely chewed wood fiber, in the sapwood and then into the heartwood. When full grown the large, thick-bodied larvae are often 2½ inches in length, creamy white, with reddish heads bearing plates armed with four spines just above the mandibles. The species is found throughout the Western States, commonly attacking Douglas fir and pines but also other conifers.

The California prionus (*Prionus californicus* Mots.) is another large species very similar to the foregoing. The larvae feed in the wood of oak, alder, poplar, and other hardwoods, sometimes boring into the roots of living trees. The adults usually have three prominent spines on the lateral margins of the prothorax. The larvae are very similar to those of *Ergates*.

SAWYERS

The larvae of the genus *Monochamus*, known as sawyers, are responsible for extensive damage to dying and recently killed and felled trees throughout the United States. The females chew irregular pits in the bark, and in these from one to six eggs are placed. The larvae, which are elongated, footless, whitish grubs, feed from 4 to 8 weeks between the bark and wood, loosening the bark and filling the space between bark and wood with long fibrous borings. Later the larvae enter the wood, forming small oval holes, that become nearly round as the larvae mature. These tunnels extend through the sapwood, often into the heartwood, and then turn outward to the bark several inches from the point of entrance, thus making U-shaped burrows in the wood. During the early stages of larval development the borings are dropped from the galleries and form small piles of sawdust. As the larva nears maturity the borings are no longer ejected, and the galleries are packed solid, with the exception of a small cell at the end of the gallery in which pupation occurs. The mature adult emerges by gnawing a round hole through the thin layer of wood and bark which separates the pupal cell from the surface. Though the life cycle of these insects is usually completed in 1 year, in the northern portion of the range two seasons are often required. The adult beetles, during flight and egg laying, feed upon the needles of conifers, and some species gnaw the bark from young twigs, many of which are killed.

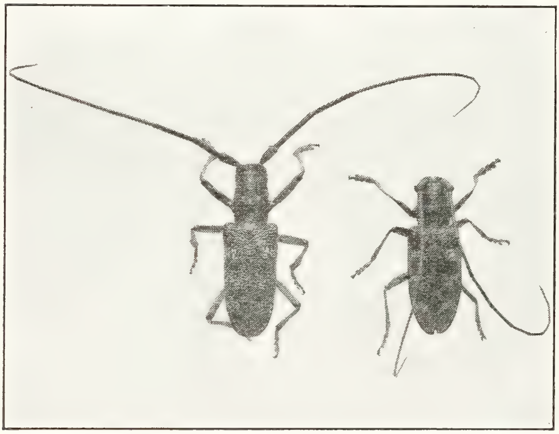

FIGURE 75.—Spotted pine sawyers (*Monochamus maculosus*), × 1.5.

The spotted pine sawyer (*Monochamus maculosus* Hald.) (fig. 75) is from one-half to 1 inch in length, drab brown, with grayish, irregular-shaped markings. The prothorax is of the same width as the head and has a prominent toothlike projection on each side. The larvae, which range from 1 to 1¾ inches in length, are destructive to fire-scorched, dying, or recently felled pines and Douglas fir throughout the Western States.

The Oregon fir sawyer (*Monochamus oregonensis* Lec.) is a stout, black beetle, approximately one-half to 1¼ inches in length, with gray markings, antennae about twice as long as the body, and a toothlike projection on each side of the prothorax. The larvae range from 1 to 1¾ inches in length and are destructive to fire-scorched, injured, dying, or recently felled Douglas fir, balsam firs, and other coniferous trees of the Western States. This is the western variety of the eastern black pine sawyer (*M. scutellatus* Say).

The obtuse sawyer (*Monochamus obtusus* Csy.) is a small brown beetle with gray markings, measuring from one-half to three-fourths of an inch in length. The antennae are over twice as long as the body, and the prothorax has a toothlike projection on each side. The larvae are from 1 to 1½ inches in length and are destructive to pine and Douglas fir in Idaho, Montana, California, and probably other Western States.

The black-horned pine borer (*Callidium antennatum* Newm.) (fig. 76) is a common species in western forests which attacks the logs and limbs of dead ponderosa pine and sugar pine. It has recently

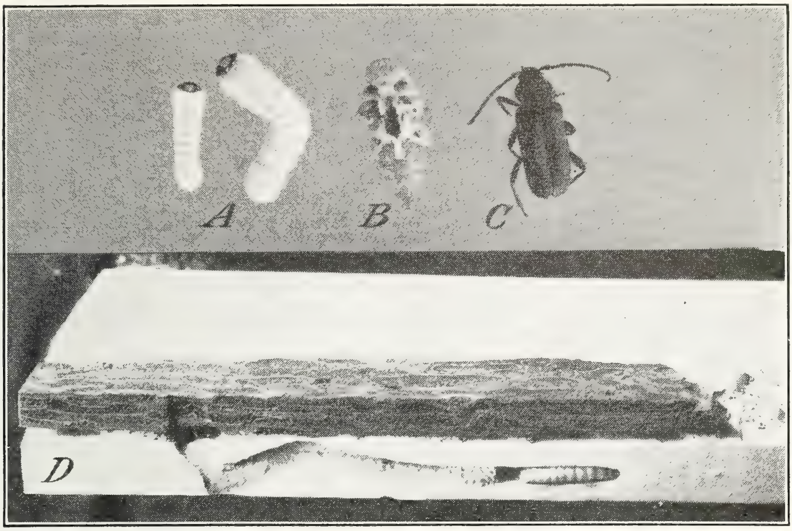

FIGURE 76.—The black-horned pine borer (*Callidium antennatum*): *A*, Larvae; *B*, pupa; *C*, adult; *D*, larva making tunnels on edging of pine board. *A*, *B*, *C*, natural size.

attracted attention as a destructive borer in lumber stored in mill yards in northeastern California, where it attacks strips of bark left on the edges of lumber stock. The larvae work under this bark and score the surface of the wood, then extend their mines into the sapwood for a depth of 2 or 3 inches. They also injure seasoned rustic work by mining out the cambium layer and causing the bark to loosen from the log. The larvae are yellowish-white, apparently legless grubs about three-fourths inch in length when full grown. The adults are flat, shining, bluish-black beetles about one-half inch in length, with antennae about half the length of the body. Other closely related species are found in the various firs, pines, cedars, and redwood.

Other species of wood-boring cerambycids which may be encountered damaging the wood of western forest trees are the following:

Species	Hosts and distribution
Tragosoma harrisi Lec.	Pines. Western States.
Asemum atrum Esch.	Pines, firs, and spruce. Western States.
Asemum nitidum Lec.	Pines, firs, and Douglas fir. Pacific coast.
Criocephalus productus Lec.	Pines, firs, and Douglas fir. Western States.
Criocephalus asperatus Lec.	Pines. Oregon and California.

Species	Hosts and distribution
Nothorhina aspera Lec.	Douglas fir. Western States.
Xylotrechus undulatus Say	Pines, firs. Douglas fir, hemlock, and spruce. Western States.
Xylotrechus nubilus Linsley	White fir. California.
Ulochaetes leoninus Lec.	Ponderosa pine, Douglas fir, and spruce. California to British Columbia.
Xylotrechus nauticus Mann	Oak, madroña, and eucalyptus. California and Oregon.
Neoclytus conjunctus Lec.	Oak, ash, and madroña. Western States.
Neoclytus caprea Say	Oak and mesquite. Arizona, Colorado, and Utah.
Brothylus gemmulatus Lec.	Oak. Colorado and California.
Synaphoeta guexi Lec.	Oak, maple, and willow. Pacific coast.
Rosalia funebris Mots	Ash, California laurel, willow and alder. New Mexico and California to Alaska.
Necydalis cavipennis Lec.	Alder and eucalyptus. Arizona and California.
Xylotrechus obliteratus Lec.	Aspen. Rocky Mountains.
Xylotrechus insignis Lec.	Willow. California.
Malacopterus tenellus F.	Willow and poplar. Arizona.
Cyllene antennata White	Mesquite. Southwestern States.

WOOD-BORING WEEVILS

(Curculionidae)

Some of the weevils belonging to the genera *Rhyncolus*, *Cossonus*, *Pissodes*, and *Cryptorhynchus* are found at times working in wood. The work of *Pissodes* has been previously mentioned (pp. 33 and 138). The *Rhyncolus* and *Cossonus* weevils are small brown or black weevils less than one-fourth inch in length, with the head produced into a snout. The larvae are white, legless, and comma-shaped. Both adults and larvae may be found boring into and destroying wood, but as the wood is usually in a decaying condition, they are seldom of any economic importance.

The poplar and willow borer (*Cryptorhynchus lapathi L.*) (*57*) bores under the bark and into the wood of poplars and willows making irregular more or less cylindrical tunnels which often so riddle the wood as to cause heavy breakage. The adults are rough, dark-colored weevils about one-fourth inch in length, with a band of bright pink across the tip of the wing covers. This is an introduced species which is gradually becoming widely distributed throughout the country. It has recently been found causing serious damage to willows along the Columbia River in Oregon.

CARPENTER MOTHS

(Cossidae)

The larvae or caterpillars of some families of moths (Lepidoptera) are wood boring in habit and mine directly into the wood of injured or weakened trees, where they may cause additional injury which may result in the tree's death. These injuries to the living tree often appear as serious defects when the tree is converted into lumber. The carpenter moths, belonging to the family Cossidae, principally attack broadleaved forest, shade, and fruit trees. The adults are large, mottled-gray moths, with spindle-shaped bodies and narrow, strong wings of medium to large size. They are night flyers and lay their eggs in bark crevices or on old wounds. The caterpillars, which are nearly hairless, have both true legs and abdominal pro-

legs but are somewhat grublike in form. Pupation occurs within the larval gallery, and when about ready to change to the adult the pupa works partially out of the burrow, so after emergence the empty pupal skin is found protruding from the tunnel.

The carpenter worm (*Prionoxystus robiniae* Peck) (fig. 77) is the most common representative of this group. It attacks oak, elm, poplar, cottonwood, locust, ash, maple, willow, and other ornamentals and also fruit trees and is distributed generally throughout the United States. As is the case with the carpenter moths, these moths cause injuries that show up later as defects in the lumber, since they mine in the sapwood and heartwood of trunks and limbs. It is probably the most destructive insect enemy of oaks in California. The adult females are gray moths with a wing expanse of from 2 to 3 inches. The males are smaller, with the front wings dark gray and the hind wings yellowish red lined with black (fig. 77). The mature larvae are about 2½ inches in length, somewhat pinkish, with a dark head and with scattered hairs arising from small brown spots on the body. Eggs are laid in June and July, each female depositing from 200 to 300. Three years are required to complete the life cycle.

Another species, *Acossus populi* Walk., does similar work in poplars and cottonwood. *Givira lotta* B. and McD. works in the outer heavy bark at the base of ponderosa pines in Colorado.

HORNTAILS OR WOOD WASPS

(Siricidae)

The horntails, or wood wasps, are injurious to the green, unseasoned or moist wood of practically all western conifers. Frequently serious damage is done, especially to the wood of fire-killed trees. Sometimes redwood lumber is attacked and injured, even after it is cured and placed in storage yards.

The adult females are thick-waisted, cylindrical wasps, with two pairs of wings and a hornlike ovipositor, which resembles a stinger, at the rear of the abdomen. They are usually of metallic colors—dark blue, black, or marked with orange and red. The females alight on freshly felled injured or dying trees and with great dexterity insert their long flexible ovipositors deeply into the wood, often for an inch or more, and lay their eggs. Sometimes they are unable to extract their ovipositors from the wood and die in this position. The larvae which hatch from the eggs are cylindrical and yellowish white, with a small spine at the posterior end of the body, and they sometimes hold their bodies in the shape of a shallow letter S. They are truly wood-eating in habit and work in the solid wood without any opening extending to the outside. As they feed they make perfectly circular holes in the wood and pack their boring dust in the tunnels behind them. It takes one or two seasons for them to complete their development. Pupal cells are constructed near the surface of the wood, and when the adults mature, they cut round, clean-cut emergence holes to the surface through which to escape.

Prompt utilization of unseasoned wood exposed to attack by these insects is the best means of avoiding damage. Logs placed in mill ponds and frequently rolled will not suffer from attacks. Kiln-drying gives complete control, destroying the infesting larvae,

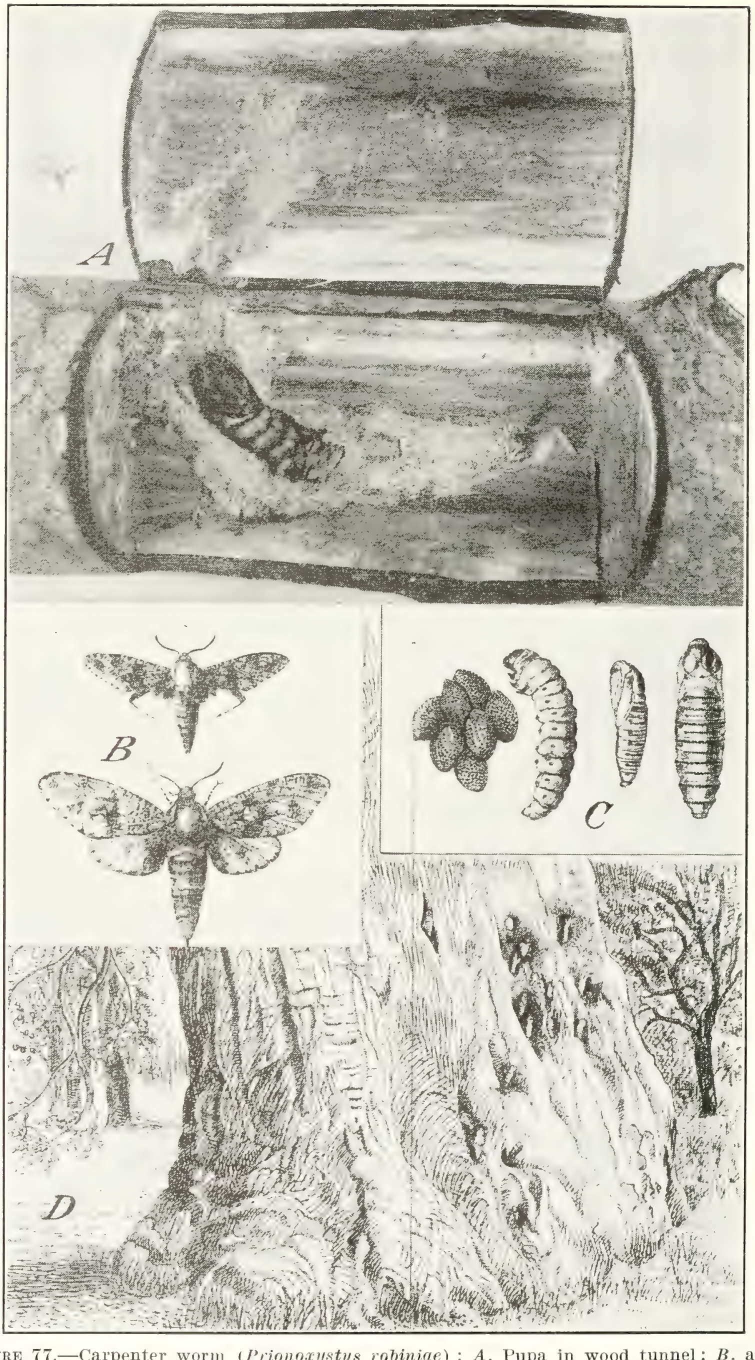

FIGURE 77.—Carpenter worm (*Prionoxystus robiniae*): *A*, Pupa in wood tunnel; *B*, adult moths, male above; *C*, egg, larva and pupae; *D*, borings in trunk of tree. (Drawings by Edmonston.) *A*, *B*, and *C*, excepting the eggs, one-half natural size; eggs × 3.

and there is little danger of these insects attacking dry, finished lumber products.

The different species of horntails are very difficult to distinguish, and many of the species have not been named or satisfactorily separated. In many cases the males and the females of the same species have been given different names, since the sexes are markedly different in appearance. Only a few of the more common ones need be mentioned.

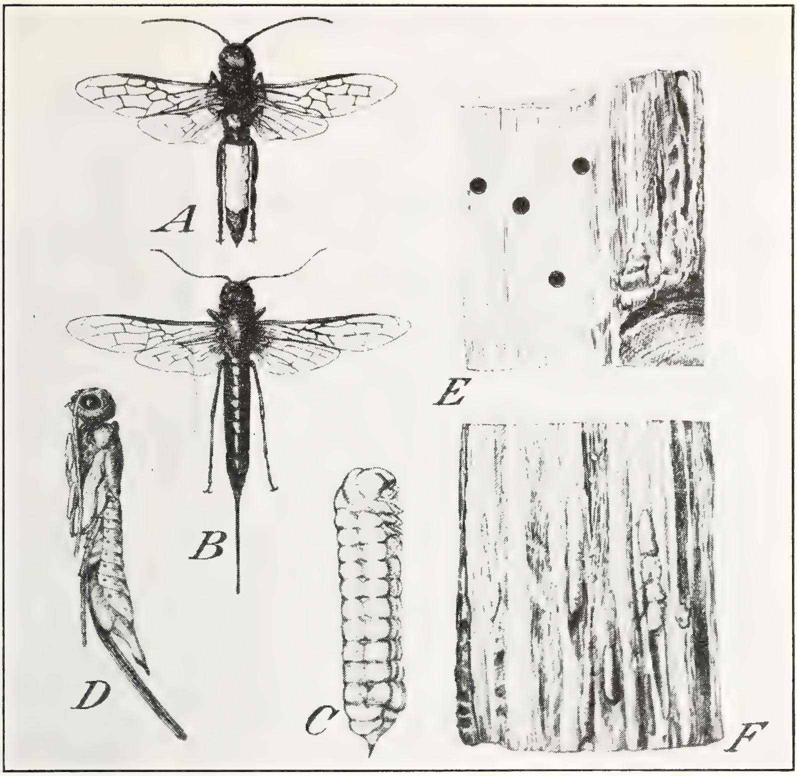

FIGURE 78.—Western horntail (*Sirex areolatus*): *A*, Adult male, × 1.5; *B*, female, × 1.5; *C*, larva, × 3; *D*, pupa, × 3; *E*, exit holes; *F*, larval mines. (Edmonston.)

Urocerus californicus Nort. is the largest of the western species. The females are dangerous-looking wasps with black bodies and legs, yellow antennae, yellow bands on legs, patches of yellow on sides of head, and amber wings. They measure from 1¼ to 2 inches in length, and the ovipositors are slightly shorter than the body. The males are smaller and have yellow bodies. The larvae infest balsam firs and Douglas fir and sometimes pine. *Urocerus flavicornis* F. is a somewhat smaller species, 1 to 1¼ inches long, and black, marked with yellow or red. It breeds in various coniferous trees, including the firs and pines.

Sirex californicus Ashm., a dark, metallic, blue-bodied species with buff-colored wings and black legs, is commonly found infesting pines. *S. juvencus* L. is also metallic blue, but the legs are dark

red or marked with yellow. It is found in pines, firs, and spruce throughout the West. *S. aerolatus* Cress. is another metallic-blue species (fig. 78), with black legs and smoky wings. This species commonly attacks redwood, cypress, and cedars, but it is also found in pines, firs, and other conifers. *S. behrensii* Cress. is a smaller species, five eighths of an inch in length, with head and thorax blue black and the apical segment of the abdomen reddish brown. The larvae infest ponderosa pine and sugar pine and have been found also in Monterey cypress.

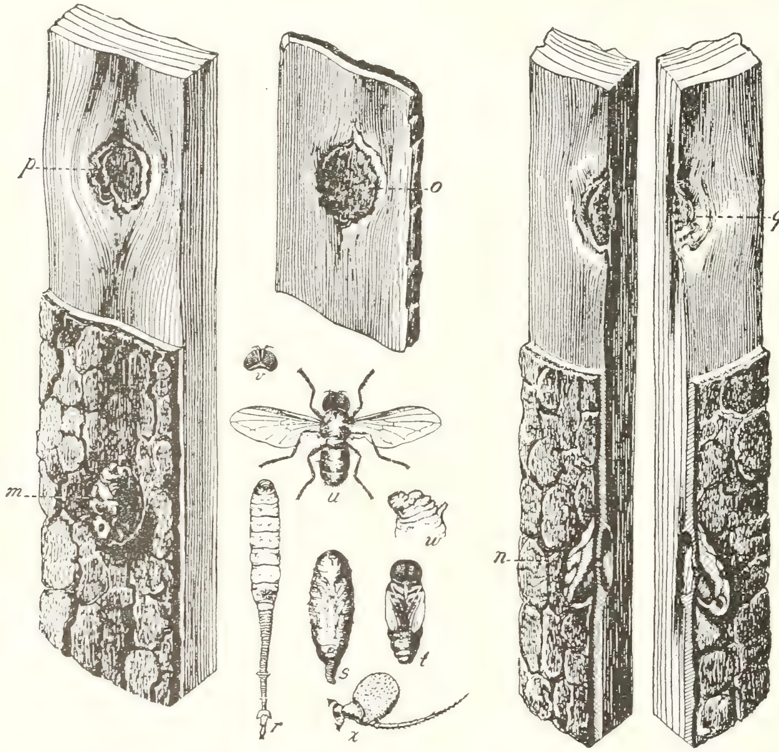

FIGURE 79.—Hemlock bark maggot (*Cheilosia alaskensis*) : *m*, Resin mass with exit hole, adult fly having emerged; *n*, longitudinal section of similar mass, showing wound in inner bark and outer sapwood, pupal chamber and exit hole in outer pitch mass, and original beetle entrance connecting them; *o*, healing wound in inner bark beneath mass like that shown at *m*; *q*, longitudinal section of wound *p*; *r*, maggot; *s*, puparium; *t*, pupa; *u*, adult male; *v*, head of female; *w*, head of larva; *x*, antenna. *r, s, t, u*, and *v* × 2; *w* × 20; *x* × 45. (Burke.)

Xeris caudatus Cress. is a very long, slim species, with an ovipositor as long as, or longer than, the body. The abdomen is wholly black and the legs yellow. The favorite host apears to be lodgepole pine. *X. morrisoni* Cress. is similar but has a reddish abdomen. It attacks firs and lodgepole pine and probably other conifers.

BARK MAGGOTS

Pecular defects in the lumber of certain coniferous trees, consisting of dark-brown or blackish resinous scars, with the wood thickened and curled, are made by bark maggots of the genus

Cheilosia (*11*). This type of defect is very prevalent in western hemlock growing in western Washington and Oregon at elevations below 1,800 feet and is called the "black check" of hemlock. These defects do not impair the wood for structural purposes but render a high percentage worthless for finishing wood, staves, or other special purposes.

The adults are small two-winged flies which lay their eggs on the bark of the trees, probably on the resin which exudes from feeding punctures made by the hemlock hylesinus. The maggots enter the bark, making a small wound, and feed on the sap and inner bark. The larvae when full grown are white maggots three-fourths of an inch in length, with the fore part of the body thickened and with a long, telescopic, protractile tail. Feeding continues for several years, then in the spring puparia are formed in the resin mass at the entrance to the wound, and the adult flies emerge in April and May.

Two species have been recognized as important in the West. *Cheilosia alaskensis* Hunter makes the black check in western hemlock (fig. 79) and is distributed from Oregon to Alaska. *C. hoodiana* Bigot does similar work in white and lowland fir in the same region and also has been reported from New Mexico. There are several other species whose habits are not fully known, which cause similar wounds in other western conifers.

INSECTS WORKING IN SEASONED OR DECAYING WOOD

POWDER-POST BEETLES

A group of beetles belonging to the families Ptinidae, Anobiidae, Bostrichidae, and Lyctidae are called powder-post beetles because the larvae burrow into hard, dry wood and reduce it to fine powder. There are hundreds of species in this group, many of which confine their attack to deadwood in the forest and are of little economic importance. Most of this group confine their attacks to the sapwood of the hardwoods, but a few species attack pine and Douglas fir and occasionally do some damage. A few work in finished products and are extremely destructive on account of their ability to reinfest wood repeatedly until it is completely destroyed and to attack any exposed surfaces of furniture, flooring, and sills, and thus establish themselves in utilized wood products.

Great care needs to be taken in storage yards to prevent infestation from developing before the sapwood of hardwoods is treated with a filler, painted, or varnished and thus protected. Badly infested stocks of tool handles, oars, or building material should be burned. If lightly infested they can be treated by soaking in kerosene or by applying liberal doses of crude liquid orthodichlorobenzene.

The Lyctus beetles (*49*, *74*) are probably the most dangerous and destructive members of this group (fig. 80). The adults are small, flat, slender, dark-brown beetles about one-eighth to three-sixteenths of an inch long. Eggs are laid in the pores of the wood, and the larvae bore only in the sapwood of various hardwoods, reducing it to a flourlike powder. The insects pass the winter as larvae. Pupation occurs in the spring, and the new adults appear early in the summer. In heated buildings development is hastened, and under such conditions adults may appear much earlier. Small round holes

in the wood from which fine powder exudes are a good indication of their presence.

Favorable conditions for attack are made when the sapwood of fine-quality hardwoods, especially of hickory, ash, and oak, is allowed to season for 2 or 3 years in undisturbed piles. Accumulations of old stock, refuse, and useless material greatly increase the hazard of infestation. Species of hardwood ordinarily not subject to the attack of these insects will, if piled with more favorable host species, share the damage of infestation. It is, therefore, evident

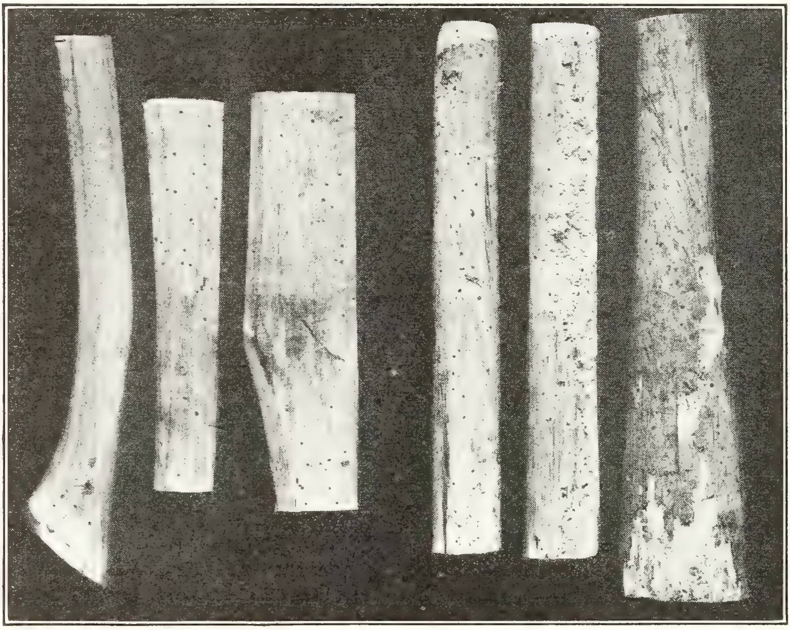

FIGURE 80.—Wood showing holes made by Lyctus beetles.

that proper methods of handling will do much to prevent these destructive pests from becoming established. Material should be inspected and rehandled annually, and all sapwood refuse, as well as stock showing signs of infestation, should be burned. Woods of different species should be piled separately and should be classified according to age of seasoning, in order that a constant turn-over in yard stocks may be maintained by utilizing or disposing of the longest-seasoned stock first. The use of heartwood instead of sapwood for piling sticks in the yard also helps to reduce the breeding ground. Kiln drying and steaming under pressure have produced gratifying control. An undesirable feature of the steam-pressure methods is that it is liable to lower the structural strength of the wood, and also there is danger of causing discoloration.

Stout's bostrichid (*Polycaon stouti* Lec.) is a large black beetle about three-fourths of an inch long, with prominent mandibles. The larvae bore in the wood of various hardwoods such as oak, eucalyptus, maple, California laurel, madroña, sycamore, and other trees in California. In several cases these large beetles have emerged from

polished table tops where these native woods were used as a base for veneer. A smaller brown species, *Polycaon confertus* Lec., also mines in the wood of these and other broadleaved shade and fruit trees in California and is sometimes responsible for the extensive killing of twigs and branches.

The lead cable borer (*Scobicia declivis* Lec.) (*17*) is an omnivorous feeder in all sorts of seasoned hardwoods, and has been particularly destructive by boring into alcohol or wine casks and into lead telephone cables. The adults are cylindrical dark brown or black beetles about one-fourth of an inch in length and have the head retracted under the thorax, giving them the appearance of bark beetles.

CARPENTER ANTS

Large black ants belonging to the genus *Camponotus* are called "carpenter ants" because of their habit of tunneling into the wood of stumps, logs, dead standing trees, or the dead interior of living trees, and even into the framework of houses, where they excavate large cavities that they use for nests in which to rear their young. The wood is not eaten by the ants, but cast out in order to make room for the nests, causing little piles of wood fibers to collect below the entrance holes. Their excavations in wood are frequently so extensive as seriously to impair its structural value (fig. 81). In the Pacific Northwest carpenter ant damage greatly exceeds and to a large extent supplants that done by termites—the termite damage being much more prevalent farther south. These ants are general feeders, including in their fare both animal food and sweets, their preferred items of food appearing to be the honeydew excreted by aphids and the caterpillars of certain lycaenid butterflies. They have even been known to shelter the aphid eggs in their nest during the winter and carry them out and place them on plants to develop in the spring.

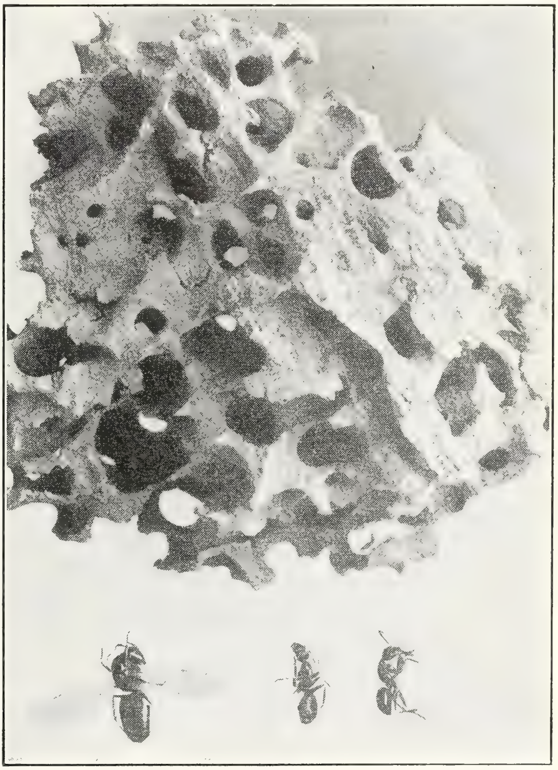

FIGURE 81.—Carpenter ants and their work. (Natural size.)

These species differ from some of the other ant species in that the queen of the carpenter ant works alone in founding a colony. An interesting feature is that, from the time the queen builds her cell and begins to lay eggs until a brood of workers mature, no food is taken into the cell. This covers a period of about 10 days from the laying of the egg to the larval stage and perhaps 30 days more before the workers are mature and begin to carry in food. It is generally supposed that the queen carries enough food within her body to feed the growing workers, apparently by the process of regurgitation.

Carpenter ants are difficult to control, and at times all remedies seem to fail. The first precaution is to prevent the ants from gaining access to foundation timbers. Where timbers are placed on solid foundations away from contact with the ground, the chance of carpenter ant attack is greatly minimized but not always prevented. The best preventitive is to impregnate foundation timbers thoroughly with creosote.

After a piece of timber has become infested, the colonies of carpenter ants can be destroyed by injecting sodium fluoride, arsenical dusts, carbon disulphide, kerosene, or orthodichlorobenzene into the nests. The sodium fluoride is probably the most satisfactory, for the ants will track through it and carry it to all parts of the nests, whereas the liquids and gases are often blocked by the tortuous, partly frass-filled cavities. If house timbers become badly infested, it is often necessary to tear them out and replace them with timbers treated with creosote. All decaying wood in the vicinity of the buildings, such as old logs, etc., should be cleared away.

LARGE CARPENTER BEES

(Xylocopidae)

Certain species of large bees, resembling bumblebees, excavate large cylindrical tunnels in dry wood in building their nests. These tunnels, especially where several colonies of bees build nests close together, may seriously weaken building timbers and telephone poles. The work differs from that of the carpenter ants in that the burrows are partitioned into larval cells by chips of wood cemented together to form circular or spiral discs. Several species of these bees are found in California and the Southwest.

TERMITES OR WHITE ANTS

(Isoptera)

The termites (*4*, *56*, *73*, *75*, *77*) are a very destructive group of wood-boring insects that excavate large cavities in wood, and at times so mine the interior as to leave only a paper-thin shell. In the forest they are commonly found in the wood of felled trees, in snags killed by bark beetles or fire, and in stumps or other sections of dead or decaying wood. Insofar as they reduce forest debris they are beneficial, but they are exceedingly destructive when they turn their attention to fences, telephone poles, buildings, furniture, or other utilized cellulose products. The group as a whole finds its greatest development in the Tropics, and in the United States does the most serious damage in the warmer southern lati-

tudes. A large number of species are found in the Southwest and southern California, but only a few extend their range into the Pacific Northwest, and northern Rocky Mountain region.

Termites are dirty-white, soft-bodied insects that live in colonies in the wood or in the ground and expose themselves to the light only when in the mature winged adult form. Each colony is made up of several specialized forms, such as workers, soldiers, king, and queen or else secondary sexual forms (fig. 82). They look like soft, fleshy ants but are distinguished from ants in having weakly chitinized body parts, except the head; and the winged forms have four wings of quite similar size and shape, while the true ants have hind wings smaller than the forewings.

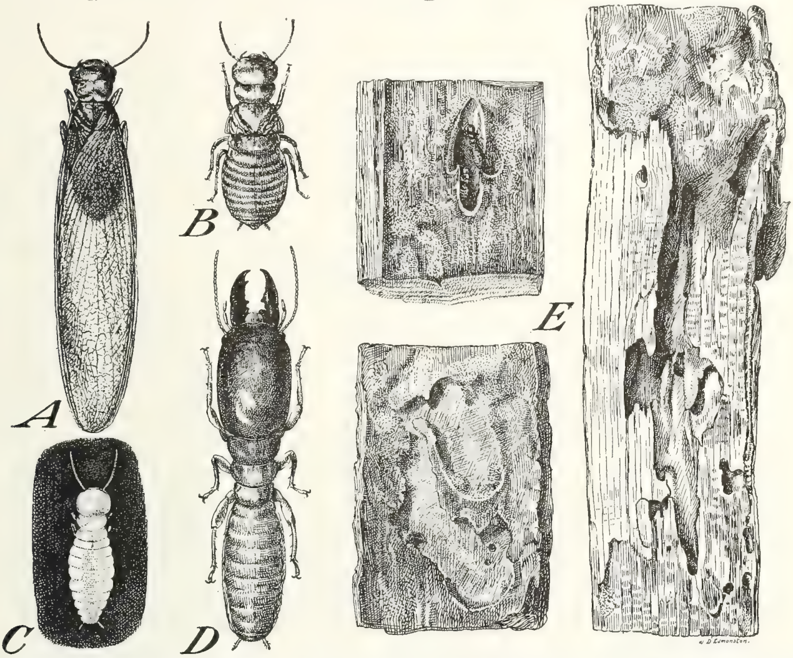

FIGURE 82.—One of the largest termites, *Zootermopsis angusticollis* Hagen, and examples of its work: *A*, Winged adult, × 1.5; *B*, second reproductive caste, × 1.5; *C*, worker, × 2; *D*, soldier, × 4; *E*, tunnels in wood. (Edmonston.)

The social life of these insects is very interesting and quite complicated. Their excavations in wood are characteristically hollow, completely enclosed, more or less longitudinal cavities, in which some species (moist-wood and dry-wood forms) deposit peculiar, small, impressed excrement pellets. The destructive subterranean form deposits its feces in the form of liquid drops, which make only characteristic spottings in their galleries.

The control of termites consists in isolating wood material from contact with the ground, or impregnating it with creosote or other termite-repellent materials. Very detailed methods of control have been devised, and it is recommended that the reader interested in this specialized subject consult one of the bulletins or publications devoted to the prevention of damage and control of these insects (*56*, *73*, *75*).

INSECTS INJURIOUS TO FOREST RANGE PLANTS

Grasses, herbage, and browse, which furnish feed to range animals, comprise a forest product sometimes of greater economic importance or value than the trees that grow on the area. These grazing plants may also suffer from insect attack and at times are so completely destroyed in certain localities that cattle and sheep have to be moved to other ranges. Moreover, the damage to browse plants may carry over from year to year and reduce the available feed for several years. Fortunately there are comparatively few insects that cause serious damage to range plants.

The damage which grasshoppers may do to the grazing areas is well known to everyone, and the insects themselves are such common pests as to require no description. They are often particularly abundant in grassy meadows, where the females lay their eggs in the ground, usually during the fall of the year, and new broods emerge each spring to feed on all kinds of green and dry vegetable matter. The nonmigratory grasshoppers remain in a given locality and produce a new brood each year, under favorable conditions becoming excessively abundant and destructive. Others are migratory in habit and, after breeding to enormous numbers, and having developed wings, travel across the country devouring every growing thing in their path.

Much attention has been given to the control of grasshoppers, and effective methods have been devised, the most satisfactory consisting in spreading poisoned baits broadcast over the breeding areas at about the time the young hoppers first come out and begin feeding. A good bait consists of a mixture of 1 pound of white arsenic, sodium arsenite, or paris green to 25 pounds of bran or middlings, 2 quarts of blackstrap, and enough water to make a thin mash.

Periodically armyworms, which are caterpillars of certain noctuid moths, appear in countless numbers and advance over grazing areas, devouring everything in their path. These also can be controlled to some extent by the application of poisoned baits similar to those used for grasshoppers, or by plowing trenches in front of the traveling army of worms and killing them in the trenches by dragging a log over them. Fortunately armyworm invasions on forest ranges are not of very frequent occurrence.

The Great Basin tent caterpillar (*Malacosoma fragilis* Stretch) appears from time to time in the Great Basin area between the Rocky Mountains and the Cascades and defoliates the bitterbrush (*Purshia tridentata*), which is a most important browse plant for sheep in this area. From 1928 to 1930 an invasion of this caterpillar swept over the range country of eastern Oregon and northern California and so seriously damaged the bitterbrush that it took several seasons for it to recover, and the carrying capacity of the ranges was greatly reduced. No practical control for this pest has been suggested, but fortunately outbreaks are brought under control by natural enemies after a few seasons of heavy feeding.

The range caterpillar (*Hemileuca oliviae* Ckll.) (*86*) feeds on wild grasses and sometimes on cultivated crops, and at intervals of 10 or 12 years is a serious range pest from Colorado southward into

Mexico. The adults are large moths with reddish, brown, or black bodies and buff or clay-colored wings. The caterpillars are yellow, gray, or black and have numerous coarse, poisonous spines.

The California tortoise-shell butterfly (*Aglais californica* Bdv.) (fig 83) is found throughout all the Western States and often appears in such numbers as to attract public attention. The caterpillars

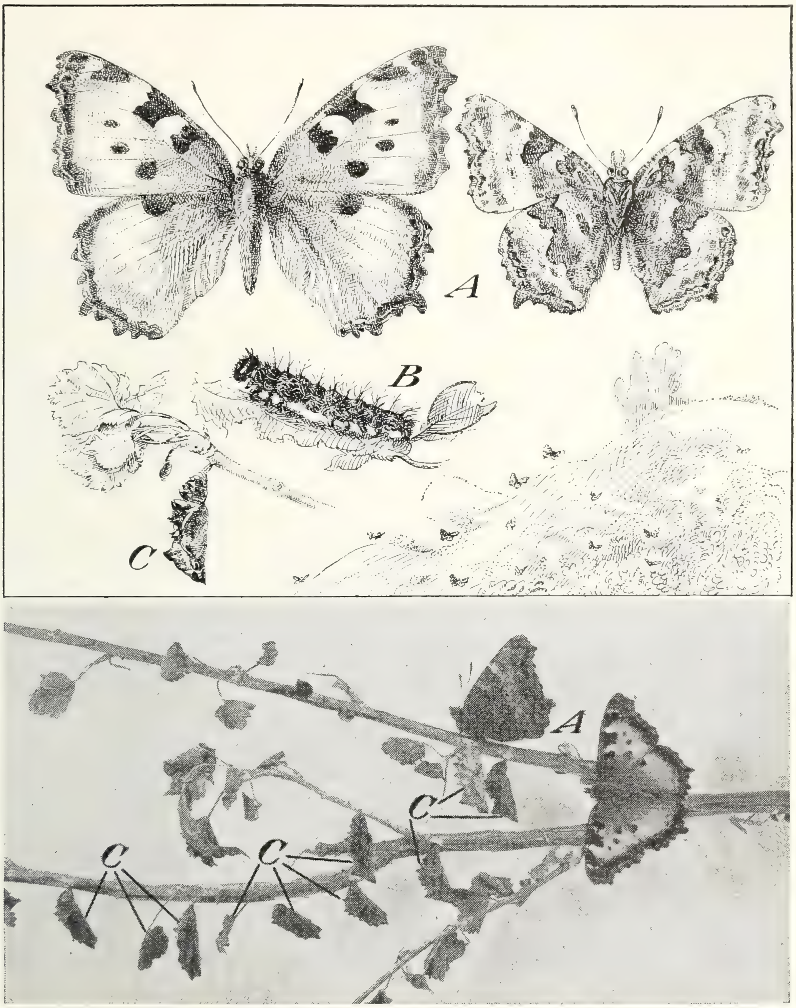

FIGURE 83.—California tortoise-shell butterfly (*Aglais californica*): *A*, Adults; *B*, caterpillar; and *C*, pendulous chrysalids. (Above) about natural size; (below) about half size. (Drawings by Edmonston.)

feed on different species of *Ceanothus*, and during severe epidemics other shrubs and trees may be attacked. The adults are medium-sized butterflies with a wing expanse of 2 to 2¼ inches. The wings are brown, with orange above, marked with black spots and black borders, with a single black spot and a marginal row of purple spots

on the hind wings. The caterpillars are 1 to 1¼ inches in length, black with fine-branched spines on each segment, the middle row being bright yellow. The adults are in flight during midsummer.

The peppergrass beetle (*Galeruca externa* Say) is a black oval beetle about one-fourth inch in length, with a narrow yellow border on the elytra, which feeds on lupine in the Great Basin area. In 1934 it destroyed the lupines over hundreds of acres in eastern Oregon and also fed on the grasses.

The range crane fly (*Tipula simplex* Doane) (*65*) at intervals is very destructive to grasslands in California. It is also a serious pest of grains, barley, and alfalfa. The adults are grayish brown, long-legged flies about one-half to three-fourths of an inch long. The females are wingless. The larvae, which are pale brown and somewhat roughened, live in small round holes in the ground, from which they emerge during the night or on dull days to feed upon any green vegetation nearby. During mild or wet seasons vast areas of range land may be almost denuded. The spreading of poisoned-bran mash, such as is used for grasshoppers, is an effective control measure.

NATURAL CONTROL FACTORS

The question is frequently asked, "Where did these destructive forest insects come from?" The answer is that in most cases they have been here as long as the forest trees on which they feed. Nearly all species of western forest insects, both injurious and beneficial, are native to these forests and are distributed throughout the range of their favorite host. Occasionally foreign pests are introduced and become established where food and climatic conditions are favorable. So far, no introduced forest insects of major importance have found their way into the forests of the West. The destructive species were already here and widely established when the forests were first examined. Given favorable conditions for their increase, they can suddenly build up their numbers from the few parents which are normally present and develop epidemics.

In the insect world a constant struggle is going on for survival. On the one hand, the insects themselves are provided with potentialities for tremendous increase. Some females lay hundreds of eggs and some species produce many generations a year, so if all individuals survived the world would soon be overrun with the progeny. On the other hand, the insects must contend with many adverse conditions that serve to hold their progeny in check. Weather conditions, food supply, prevalence of natural enemies, and many other environmental factors influence their abundance. Some of the more important of these factors will be considered.

CLIMATIC AND ENVIRONMENTAL INFLUENCES

Climatic factors, such as temperature, moisture, and weather conditions in general, have an important bearing on the abundance, activity, and distribution of insects.

TEMPERATURE

Insects as a rule have a very small range of temperatures (50°–95° F.) within which they are the most active; and the optimum for

many of the Temperate Zone species appears to be about 77°. Temperatures either above or below this optimum range limit activity and extremes cause death (*62*, *63*). Few insects can withstand temperatures above 120° and this makes possible the control of many species of bark- and wood-boring insects by raising the temperature of their environment to fatal heights. Low temperatures also are fatal. It has been found that larvae of the western pine beetle are killed when exposed to a temperature of −10° and extremely cold winters with air temperatures below −20° have proved fatal to a high percentage of this and other bark-beetle broods (*4a*) (*55a*). Moreover, elevation and exposure modify temperature and limit the distribution of insect species, regulate their activity, and govern the number of generations per year.

MOISTURE

Moisture has an important bearing on insect abundance, both through its direct effect upon the insects and indirectly through its influence upon the host. Some insects require very moist conditions under which to work to best advantage and are killed by dryness; others require very dry conditions and are killed by moisture. Moreover, moisture through precipitation has an important influence upon the growth and resistance of trees to bark-beetle attack; and periods of drought are frequently followed by serious consequences in supplying insects with an abundance of weakened host material.

FOOD SUPPLY

The abundance or scarcity of the food supply is an important consideration in determining the distribution and successful development of insect progeny. Most of the insects which prey upon living forest trees are limited in their distribution to that of their favorite host, whereas those which feed upon dying or dead trees are apt to be widely distributed throughout forest regions.

Insects, such as the defoliators, that attack healthy forest trees always have an abundant food supply at their disposal, and their numbers are controlled primarily by biological and climatic factors. On the other hand, a great many insects, such as most of the bark beetles, can develop in large numbers only when a sufficient quantity of their food material in a suitable condition for attack is available. Thus the development of certain destructive bark-beetle outbreaks is dependent to a large degree upon a supply of overmature or decadent trees, fire-weakened trees, slash, windfalls (*61*), snow-broken or lightning-struck trees, or trees weakened by drought, smelter smoke, disease, or other causes. Under favorable conditions, however, a few species of bark beetles can develop in epidemic numbers without such contributing factors.

In the virgin pine forests of the West, a high percentage of the trees are mature or decadent. They grow more slowly, and resistance to beetle attack is lessened in other ways during periods of drought. Such conditions present a highly favorable field for bark-beetle activity, and the heavy losses that have been sustained in the pine regions during the past few years indicate very clearly that the bark beetles have not neglected this opportunity.

Trees that have been felled by wind or snow and those struck by lightning furnish favorable breeding places for a great many destructive bark and wood borers. Such material is probably the natural habitat for many species that at times become excessively abundant and attack living trees. Many severe bark-beetle epidemics are known to have originated in areas of wind-blown timber.

SLASH

The debris left from the cutting of trees in the forest is a suitable and attractive breeding ground for a great many forest insects, some beneficial and some harmful (*37*, *67*, *84*). When slash is freshly produced, the dying inner bark is attractive to many species of bark beetles that are commonly found breeding in standing trees. Usually these bark beetles select in the slash or stumps the type and size in which they normally breed. Thus the limb- and twig-feeding bark beetles go into the brush and smaller pieces of slash, trunk-breeding bark beetles go into the cull logs and butts, and those that normally work at the base of the tree attack the stumps. The abundance of the progeny depends a great deal upon the moisture and temperature conditions within the slash and the requirements of the different species of beetles. The red turpentine beetle, which breeds readily in pine stumps, frequently develops in such numbers as to do serious injury to adjacent forest trees. The trunk-breeding pine beetles rarely find suitable conditions in the cull logs and butts, and the progeny which they produce under such circumstances seldom cause any trouble in neighboring forests or to the reserve stand, especially where logging operations are continuous. The engraver and twig beetles, which breed in the smaller pieces of slash, frequently emerge in such enormous numbers as to kill patches of young trees and sometimes the tops of older trees.

The wood-boring species that breed in slash must be considered generally beneficial, in that they help to decompose the wood and reduce the slash with its accompanying fire hazard.

They may become injurious, however, and in order to avoid or reduce a possible menace from slash-breeding insects special considerations in slash disposal are frequently necessary. When a logging operation is continuous, and a fresh supply of slash is furnished throughout the flight period, the emerging progeny is repeatedly absorbed in the slash and in the logs removed to the mill, and no special precautions need be taken. But if a cutting operation ceases or is intermittent, as in the case of road and power-line development, then some damage from slash-breeding insects may be expected and should be avoided if possible. Burning the slash is beneficial provided the large limbs, cull logs, and stumps are included and the burning done before the insects emerge. In many cases this would mean that the burning would have to be done in the middle of summer or early in fall, and this would not be safe from the standpoint of fire hazard. Spreading the slash so as to receive the direct rays of the sun is effective in disposing of a high percentage of the insects in the more southern latitudes where high temperatures can be attained in and under the bark in this way.

FIRE

Trees scorched or killed by forest fires are particularly attractive to a large number of forest insects, which may be drawn to them from a radius of several miles (*64*). Subsequent insect damage augments the fire losses, as bark beetles often kill many trees which otherwise might have survived. Wood-boring species then enter the wood and so riddle the interior that within a few years it becomes valueless for lumber purposes.

Forest fires are not of any benefit in destroying injurious bark beetles, as is sometimes supposed. Sometimes light burning has been advocated as a means of controlling bark beetles, but studies have shown that such fires are more apt to have the opposite effect. Destructive, tree-killing bark beetles never breed in and seldom inhabit the forest litter and duff and hence are seldom killed by light ground fires, and can only be killed in the trees by a fire severe enough to kill the bark on the trunks. Such a fire obviously would do more harm than good.

NATURAL ENEMIES

Insects, like other living things, have natural enemies that prey upon them and tend to hold them in check. Three of the most important of these are birds, disease, and other insects.

BIRDS

Many species of birds are insectivorous. Nuthatches, chickadees, creepers, warblers, kinglets, and many other species search for insects on tree trunks and foliage, while woodpeckers dig through the bark and feed on larvae of bark beetles and wood borers. Counts have shown that fully 75 percent of the western pine beetle population in patches of pine bark worked over by woodpeckers have been destroyed by these industrious workers. But not all birds are beneficial in this respect. Some are as destructive to beneficial insects as to the harmful species, and their feeding has ultimately little effect in reducing the injurious forms.

DISEASE

Insects are subject to many fatal diseases, that sometimes are a potent factor in suppressing an outbreak of some harmful pest. These diseases are represented by many different micro-organisms, including bacteria, fungi, and the causes of polyhedral bodies. Few of these have been adequately studied. One of the most common examples is a wilt disease that spreads rapidly through outbreaks of various caterpillars when these are excessively numerous. The caterpillars suddenly sicken and die and are seen hanging from leaves and twigs in a blackened, shriveled condition.

BENEFICIAL INSECTS

Many species of insects belonging to different orders and families are distinctly beneficial in that they devote their lives to preying upon certain harmful species (*51*). These beneficial forms may be

divided into two large groups, (1) the parasites, which live in, on, or with some particular host and gradually consume it, and (2) the predators, which feed externally and devour their prey. The line of demarcation between a parasite and a predator is not a rigid one, since both live at the expense of their host. A parasite is usually considered as one capable of completing its life history in or upon the body of one host, whereas a predator feeds on a succession of individuals. Often both the immature and adult forms of predacious insects feed directly on all stages of their insect hosts.

Most of the parasites belong to two or three families of wasps (Hymenoptera) and one family of flies (Diptera). The wasps frequently have long ovipositors with which they deposit their eggs, often within the body of their insect hosts. Here the egg hatches and the young parasite grows to maturity, feeding on and finally killing its victim. Flies lay their eggs on the surface of the host, and the maggots burrow within. Native forest insects are plentifully supplied with parasitic enemies. Unfortunately, even the beneficial insects are not immune from attacks of other parasites, called hyperparasites. Hyperparasitism is occasionally carried to the third and fourth degrees, making parasitism an extremely complex relationship.

The most active predacious insects are beetles belonging to the families Cleridae, Ostomatidae, Carabidae, and Coccinellidae; lacewing flies of the family Chrysopidae; and several families of true bugs belonging to the order Hemiptera. Other important predators include such small mammals as chipmunks, mice, and shrews (*71a*).

The larvae of some of the roundheaded borers are very voracious bark feeders and are often unwittingly beneficial in that they devour the inner bark so rapidly as to rob the bark beetles of their food. This is a case of competition between two species of insects, one of which is capable of killing trees and the other harmless in this respect, with the harmless species depriving the destructive one of necessary food material.

Under normal conditions, the operation of these physical, nutritional, and biological forces counteracts the enormous reproductive capacity of the insects and tends to keep the destructive and beneficial insects more or less in balance. The few harmful individuals which escape their enemies live and feed on their hosts without doing conspicuous injury. The defoliating insects feed on a few leaves or needles, but the damage is so small as to escape notice. The bark beetles kill an occasional tree or breed in down logs and broken tops. The aggregate damage is negligible, and the annual growth which the trees acquire exceeds the drain, so that there is a net accretion of volume in the stand. Insect infestations which continue under these conditions are termed "endemic." This is the normal condition in nature and it is a hopeless and unwise undertaking to try to exterminate native insects under such conditions. The result of an effort in this direction would be more apt to disrupt the delicate balance than to accomplish the objective.

Under certain conditions, the natural balance may be broken by any one of a number of factors. For example, the beneficial insects or other enemies of harmful species may become reduced in numbers; the resistance of the trees may be lowered through drought, fire, or stagnation; large quantities of slash or other breeding material may

become available; or climatic factors may become especially favorable. Under any such condition the injurious species will breed rapidly and in excessive numbers, and a sudden destructive outbreak soon develops. Within a few seasons a high percentage of a timber stand may be killed by bark beetles. Such epidemics may continue for years and spread over large areas. Defoliators may suddenly appear within an area and, after destroying the foliage of valuable timber over large acreages, disappear with equal suddenness. Many factors come into play in bringing about these sudden changes, and it is often difficult to isolate the responsible causes. Outbreaks of such a character are called "epidemic" infestations and require immediate attention and drastic control.

CONTROL OF INJURIOUS FOREST INSECTS

The objective in forest-insect control, in areas not under intensive management, is to prevent or suppress epidemic outbreaks of injurious insects and to prevent their spread. As has just been indicated, it is best not to disturb normal infestations of native insects, for there is small hope of exterminating them, and the complicated factors that hold the species in balance may be unfortunately disrupted. Control of native pests is therefore confined to the preventing of threatened outbreaks and the suppression of those that have attained some proportions. In the case of defoliators, the object is to hold down the injury to as low a point as possible until natural factors suppress the epidemic. In bark-beetle control the objective is to prevent or suppress the development of a large beetle population, at the same time giving every encouragement to the natural control agencies, so that the natural balance may be restored.

The control of forest insects, scattered as they are over vast forest areas, may seem an insuperable undertaking, and yet certain methods are available that make this not so hopeless a task as it might appear. Control problems my be approached in at least three different ways: (1) Through such direct remedial methods as destroying the insects by burning, drowning, or poisoning; (2) by silvicultural methods that modify the physical or nutritional forest conditions so as to change temperature, moisture, or food supply; and (3) by biological methods that alter conditions so as to increase the numbers of natural parasitic or predacious enemies. Though these are distinct methods of approach, it is often necessary to utilize more than one of them in the solution of some forest-insect problems.

Forest-insect control in the Western States is, at the present time, largely a matter of protecting mature timber stands from the ravages of insects through the application of direct remedial control measures. But as mature timber stands are cut and brought under management, there will be more and more opportunity to apply silvicultural measures in the solution of forest-insect problems. The application of biological methods will depend largely upon what is discovered through further research work as to the various interrelationships of the insects concerned.

The control of introduced or foreign pests presents quite different problems. In the first place, every effort is made to prevent their introduction into this country through rigid quarantine inspections made at all ports of entry. Such pests as escape detection and become

established in the country are hedged about with domestic quarantines for the prevention of their further spread, while every effort is made to exterminate them before they have become so firmly entrenched as to make such efforts impractical. If these efforts fail, a search is made in their native homes for the specific parasites and predators which normally hold them in check there, and these are introduced and their establishment attempted in this country. Work of this sort has been highly successful in controlling many foreign pests that have been inadvertently introduced.

SILVICULTURAL CONTROL

When timber stands are brought under management, it becomes possible so to regulate conditions as to make forests less vulnerable to insect attack; or if insect damage does occur, to salvage the timber without undue loss. The underlying aim is to maintain a biological balance throughout the period of rotation. This task is hardly as simple as it sounds and cannot be accomplished without a thorough understanding of all the factors contributing to insect abundance and the resistance of forest stands. The possibilities in this direction have not as yet been fully investigated, and there is still much to be learned about the management of western forest types before thoroughly sound methods of procedure can be recommended with complete assurance of success.

It is apparent, however, that this field of silvicultural control offers almost unlimited possibilities. In the older forests much can be done to lessen insect damage by avoiding injury to the trees from forest fires and other weakening influences; by keeping forests in a healthful condition through disposal of windfalls, slash, and other insect-breeding places; and by selective cutting operations to remove the trees most susceptible to insect attack, and through these cuttings to regulate forest composition and density. In new plantations consideration should be given to the selection of the site and the planting of species and varieties of trees best adapted to it, to their proper spacing, and to the regulation of drainage, temperature conditions, and stand density. Mixed stands are also less susceptible to serious injury than pure stands. These are just a few of the possibilities that suggest themselves in which insect activity can be modified through silvicultural practices.

In the overmature virgin forests of ponderosa pine, bark beetles are not indiscriminate in their attacks but make a selection of certain trees or groups of trees scattered through the stand (*70*). A study of the types of trees selected has shown that in general the more slowly growing trees, the codominants and intermediates in the stand, and the older age classes are selected in preference to the thrifty, dominant, young trees (*55*). The damage in these pine forests also becomes more acute when the stands are suffering from stagnation or are subjected to periods of drought, and the soil moisture is not sufficient to keep all of the trees in a thrifty, growing condition. A selective cutting to remove the more beetle-susceptible trees, to release the stand from stagnation, and to give the more thrifty dominant trees first chance for such moisture as may be available is the most obvious solution. Instead of cutting heavily on small logging units forest management is looking toward a light selective system where-

by large areas will be opened up so that insect-killed trees can be quickly salvaged and stands improved from the standpoints of both growth and insect resistance.

Under management, the age at which certain stands become susceptible to beetle attack will necessarily be taken into consideration, and a cutting rotation adopted that will permit the timber crop to be harvested before the beetle hazard becomes too great. Lodgepole pine is a good example of a tree whose short life is largely a result of periodic, devastating outbreaks of the mountain pine beetle.

In some cases stand composition and density will have to be regulated to avoid serious damage from insect attack. Pure stands, which are those composed of a single tree species, are particularly susceptible to disastrous outbreaks. For instance, outbreaks of the hemlock looper have been especially destructive only in stands composed of a high percentage of hemlock. Where a heavy mixture of other species occurs the infestation soon thins out and loses its destructive power. Attacks of the spruce budworm also have been most destructive in stands composed of a high percentage of balsam and Douglas firs. It is particularly important that cuttings, in stands that normally grow as mixed types, should not favor the leaving of a single species. This is not so important in stands that normally occur in nature as pure types, for in such cases there is usually a natural balance between the tree species, the vegetative ground cover, and the insects that are associated in this type of forest.

The stand density has an important bearing upon temperature and moisture conditions and in many cases must be regulated so as to improve growth rates and discourage the attacks of certain insects.

Many of these problems of silvicultural control become increasingly important when new plantations are established. Sites must be selected which are adapted to the growing of trees, or growth will be so poor and the trees so weak that insects will have a fertile field for their activities. Here, too, there is the opportunity to select varieties of trees that are not only adapted to the particular site but are insect-resistant or capable of making such rapid growth as to overcome any set-backs from insect attack. Drainage, the mixture of species, and the spacing of the trees also must be given special consideration.

BIOLOGICAL CONTROL

As has been previously mentioned, parasitic and predacious insect enemies and insectivorous birds and mammals are often of great value in holding destructive forest insects in check. To increase the effectiveness of these natural control agencies through artificial means offers hopeful possibilities but is beset with many difficulties.

Where native insects which already have a full complement of natural enemies are concerned, an effort can be made to create favorable conditions for the multiplication of these beneficial agencies. Direct control methods, such as burning or sun-curing, can be modified so that the beneficial insects will not be destroyed in as large numbers as the harmful species. Sometimes only a slight change in this direction will give the beneficial insects the upper hand, and they will quickly bring an epidemic back to normal balance. To increase

these native insect enemies through artificial propagation presents seemingly insurmountable difficulties with little hope of any lasting benefit.

Another possibility is the introduction of a new parasitic or predacious enemy. To do this, it is first necessary to find an insect not already present within the infested area that will prey upon the harmful species. Even though such an enemy may be found, there are many complex factors which will influence the success of the introduction and its ultimate effectiveness. The life history of the new enemy must synchronize with that of its host if it is to be on hand at the proper time for attack. If a parasitic enemy has more generations annually than the host, other insects must be present for it to attack at other periods during the season. The parasite must be capable of wide distribution and have a greater reproductive capacity than that of its host if it is to succeed. Moreover, its ability to adapt itself to the change in climatic conditions in its new environment may be an important factor in determining its ability to succeed. So far, no introduction of a foreign parasite or predator has been outstandingly successful in the control of any of our native forest insects.

The introduction of parasites and predators has been confined largely to cases where injurious insects have been accidentally imported into new regions while their natural enemies have been left behind. Under such conditions the introduction of parasites from the original home of the pest have, in several instances, been entirely successful, although the continuation of artificial control has frequently been necessary. In only a few instances have introduced beneficial insects been able to control destructive epidemics completely without other assistance.

In view of the fact that the application of biological control measures often presents almost insuperable difficulties, a thorough knowledge of all associated insects is of vital importance, in order that the more direct control methods may be applied so as to take full advantage of any aid from parasites and predators.

DIRECT ARTIFICIAL OR REMEDIAL CONTROL

When nature fails to keep an injurious insect in check, and valuable forest crops are threatened with destruction or serious injury, direct remedial or artificial control measures are called for. These consist in such mechanical methods as the application of insecticides, as in spraying, dusting, fumigating, or baiting; felling or burning infested trees; or the use of trap trees or solar heat. In brief, these artificial control measures are employed to destroy the harmful insects directly in one way or another.

The control measures applicable to the control of cone and seed insects, root-feeding nursery pests, terminal or twig insects, and insects injurious to forest products have already been considered in connection with the discussion of these special groups. The control of defoliating insects and bark beetles affecting mature forest trees has been given special attention in western forests, and, since specialized methods have been developed, these will be given detailed consideration.

CONTROL OF DEFOLIATING INSECTS

Defoliating insects can be controlled through the use of chemical poisons. Chemical control has been in use for many years, but until recently the control of tree defoliators by such methods has been limited to orchard, park, and shade trees. However, the application of these methods is gradually being extended to forest trees. In general, two types of poisons are used in this work, (1) the stomach insecticides and (2) contact insecticides. These may be applied in the form of either dusts or liquid sprays (fig. 84).

FIGURE 84.—High-pressure spraying outfit used along highways of the Shoshone National Forest, Wyo.

The stomach poisons are used against insects that chew their food, such as the leaf-eating caterpillars, sawflies, and beetles, and when applied directly to the foliage become effective against the insect through its mouth and digestive tract. The most useful poisons for this purpose are various arsenical compounds such as lead arsenate and calcium arsenate. Lead arsenate and calcium arsenate are not only toxic to the insects but contain comparatively little free arsenic and hence are not harmful to the foliage of many trees when used with discretion. Calcium arsenate is the cheaper of the two, but lead arsenate is somewhat more effective and less injurious. A spreader is usually added to the liquid sprays in order to make them spread evenly over the surface of the foliage and to adhere well. Fish-oil soap, linseed oil, glucose, resin stickers, and similar substances are frequently used for this purpose.

The stomach-poison spray most frequently used for the control of leaf-chewing defoliators consists of the following:

Lead arsenate, paste (or lead arsenate, powder, 3 to 5 pounds)	5 to 6 pounds.
Water to make	100 gallons.
Fish-oil soap	1¼ to 1½ pints.

Contact insecticides are used against small sucking insects such as the aphids, scales, and bugs, and sometimes against small caterpillars and leaf miners, and are applied in the form of liquid sprays or dusts so as to come in direct contact with the insects. These poisons kill the insects by entering the respiratory system, or by penetrating through the thin body membranes, or they may destroy them by plugging their breathing tubes, paralyzing the nerve centers, or actually burning the insects through the caustic properties of the chemicals. The young insects are much more easily killed by such treatment than the older forms, which often become protected or more or less resistant.

There are a large number of contact sprays and dusts, each with certain advantages and special fields of usefulness. Only a few will be mentioned here, since the contact sprays, while very useful in the control of shade-tree pests, have not as yet been used in the forests of the West.

One of the most useful contact sprays is 40-percent nicotine sulphate diluted with water in the ratio of 1 to 800 or 1 to 1,000, to which is added about 1 ounce of soap to each gallon of spray in order to give good spread and adhesion. This spray is particularly useful in the control of aphids and other soft-bodied insects. A typical formula is—

Nicotine sulphate, 40-percent	1 pint
Fish-oil soap	5 pounds
Water, to make	100 gallons

Miscible oils, or oils that will mix with water, have come into prominence in recent years as effective contact sprays for shade and orchard trees, and are useful in nurseries and plantations against such forest pests as the spruce bark louse, the green spruce aphid, and various scales. These oils are proprietary products, sold under a variety of names, and vary somewhat in strength. The winter oils are used as dormant sprays and will injure foliage if applied when the trees are in leaf. Lighter or summer oils are also available that can be applied to the foliage without injury. Instructions as to dilution of the oils come with the product. Fish-oil soap is usually used as a spreader.

Soap and kerosene emulsion have been used in the past, but results from their use are uncertain, and they are no longer recommended for shade-tree sprays.

Lime sulphur is a very effective and inexpensive spray which is used in the control of the armored scales. It is applied during the winter or early in the spring as a dormant spray. The concentrated preparation should have a density of about 30° Baumé and should be diluted with eight parts of water.

Many other insecticides are available, and various combinations of ingredients are used for special purposes. Some of these may be very harmful to plants and dangerous to use. If special problems come up requiring the use of chemical insecticides, it is best to consult an entomologist before entering on any extensive control project.

Spraying

Liquid insecticides, either stomach or contact poisons, when used in the control of tree-defoliating insects, are applied in the form of a

spray by means of power spraying apparatus. Such methods are commonly used in the control of park- and shade-tree defoliators, but under forest conditions can be used only along roads or at camp sites and resorts where it is possible to transport the heavy equipment. Because of the height of forest trees, high-power spraying pumps are a necessity. Even the largest spraying equipment so far developed is not adequate for the tallest trees.

FIGURE 85.—A long hose permits reaching out for distances of 1,500 to 5,000 feet from the spray pump.

Spraying for the control of the spruce budworm has been carried on for several years in the Shoshone National Forest, Wyo., along highways and around summer resorts. One of the largest spraying outfits so far developed has been used in this work. This consists of a three-cylinder power sprayer with a capacity of 25 gallons per minute through ¼-inch tip under a nozzle pressure of 150 to 300 pounds. This pump is mounted on a motor truck that carries from 1,500 to 5,000 feet of hose to reach out on either side of the road (fig. 85). This equipment can shoot a stream to a height of 90 feet when a $^{5}/_{16}$-inch tip is used. But even this powerful equipment

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would not be adequate for the spraying of trees over 90 feet in height or for reaching out into inaccessible forest areas.

Airplane Dusting

Although most defoliating insects can be easily killed by properly applied insecticides, their control is not a simple one owing to the great difficulty of application (*33*, *81*). Outbreaks of forest defoliators often cover large areas in inaccessible terrain and affect some of the tallest forest trees that cannot possibly be reached with any dusting or spraying apparatus operated from the ground. For these reasons the only feasible means of applying insecticides to large forest areas is from the air and in recent years the airplane has come into use for this purpose. Dry dusts are best adapted for this purpose, but in some recent orchard work liquid sprays have been used. Calcium arsenate is the dust most frequently used as a stomach poison for airplane dusting against leaf-eating insects.

Figure 86.—Loading hopper and airplane used in forest-dusting operations in Washington in 1931.

Airplanes for dusting are equipped with a hopper to carry up to 1,000 pounds of dust (fig. 86). Inside of the hopper is an agitator to keep the dust stirred up, and at the bottom of the hopper is a sliding gate that can be opened and closed from the pilot's seat. This opening allows the dust to be discharged into the air stream, which catches it and whirls it groundward in a vast cloud. The airplane is required to fly very low (fig. 87), and when it is flying at a height of 40 feet above the tree tops the dust cloud settles over a width of about 150 feet. The airplane flies back and forth letting the strips of dust overlap slightly. The flying must be done when wind movement is negligible and preferably when there is dew on the foliage that will help to hold the dust. In some recent dusting for the hemlock looper (*54*) (fig. 87) the dust was applied at the rate of 20 pounds per acre, but in heavy forest stands the dosage must be increased up to about 60 pounds per acre. The cost of the work ranges from $3 to $6 per acre and this expense is justifiable only for the protection of particularly valuable timber.

Airplane dusting has certain disadvantages that prevent its general adoption as a satisfactory method of controlling forest defoliators. It is expensive and very dangerous, since the airplane must fly so close to the tree tops. Even under good conditions, an even distri-

bution of dust is extremely difficult to obtain, owing to slight wind movements and irregular topography, and in order that dosages on the foliage may be lethal, a great deal more dust must be applied than would ordinarily be required in the ground-dusting of small trees.

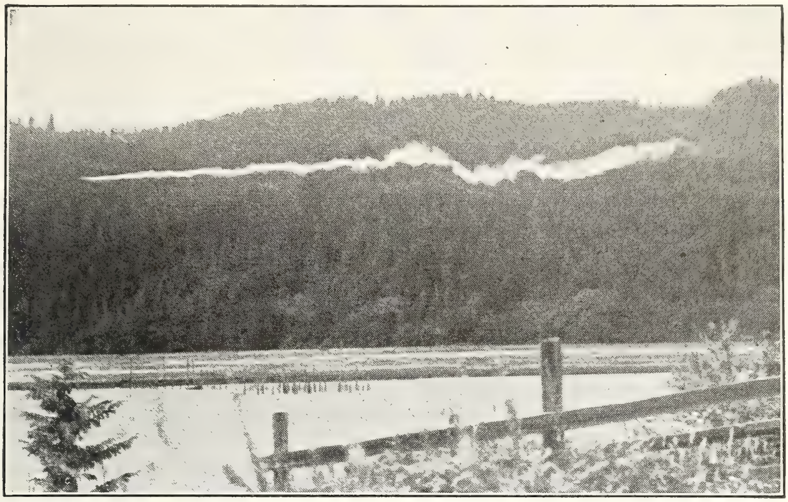

FIGURE 87.—Spreading calcium arsenate dust from an airplane in dusting operations against the hemlock looper in Washington.

Furthermore, the question as to the effect of heavy applications of arsenicals to large forest areas has not been fully answered. In its present stage of development airplane dusting cannot be recommended for general use in the control of forest defoliators.

BARK-BEETLE CONTROL

A tree in which bark beetles have successfully established themselves cannot be saved, and the best that can be done is to destroy the infesting insects before they are able to emerge and attack other trees (*50*). Bark-beetle broods can be destroyed by several methods of artificial control,[8] the method and time of application varying for different species and different regions. Though bark-beetle outbreaks can be reduced, these insects cannot be exterminated, so control measures must not be considered as a panacea or cure for all time. The results of a sucecssful bark-beetle control project may last for years or they may be of extremely short duration.

In justifying the application of measures for the control of bark beetles, such factors as the value and merchantability of the timber, the destruction of the forest cover in its relation to watershed protection, the creation of fire hazards, and the danger of the epidemic spreading into more valuable stands of timber must be considered. The proper evaluation of these factors, balanced against the cost of the operation, will determine the economic justification of the project. However, it is difficult to foresee the extent of the probable

[8] KEEN, F. P. MANUAL OF BARKBEETLE CONTROL IN WESTERN PINE FORESTS. U. S. Dept. Agr., Forest Serv. 58 pp., illus. 1927. [Mimeographed.]

damage or the course the epidemic may take if no control is undertaken, and conclusions as to the success of a bark-beetle project can only be deduced on the basis of an estimate of what would have happened if no control work had been undertaken. Control measures applied during the decline of an outbreak often tend to place an inflated value upon the results obtained. On the other hand, control undertaken during the time an outbreak is building to an epidemic may show little reduction in damage and give the appearance of failure. The best that can be done is to compare the trend of the epidemic on the treated area subsequent to control with that on a similar neighboring area where no work was done.

To protect valuable forest areas from bark-beetle outbreaks certain steps should be taken. These may be summarized as follows:

(1) A general reconnaissance or detection survey of valuable forest types subject to bark beetle epidemics should be made each year to detect the beginning of any outbreak. If an outbreak is indicated, a decision should be reached by the owners or those responsible for forest protection as to whether timber values in or adjacent to the site of a detected outbreak warrant the probable expense of a control operation. If so—

(2) An extensive bark-beetle survey should be undertaken, usually under the supervision of a competent forest entomologist, to determine (*a*) the trend of the outbreak and the possibilities of natural control; (*b*) The area involved in the infestation and threatened by it; (*c*) what areas must be included in the control program; (*d*) the number of trees that will require treatment, and the area that must be covered in the first season; and (*e*) the probable cost and results to be expected. In the light of the complete information furnished by the extensive survey, a decision can be reached as to the need and justification for applying artificial control measures, and whether or not the necessary cooperation of all affected owners can be obtained and the work adequately financed. If control work is decided upon, then—

(3) A control campaign should be outlined and prompt and thorough control measures should be applied to all units showing epidemic trend within the project area. This should be followed by treatment of such outlying areas as may jeopardize results in the cleaned units.

(4) A maintenance control program should be continued until a natural balance has been restored.

Detection of Bark-Beetle Outbreaks

If forests are to be protected from serious damage or destruction by bark beetles, incipient outbreaks must be promptly discovered and reported. If such a system is consistently carried out, it will greatly reduce the ultimate cost of protection and prevent the building up of disastrous and uncontrollable infestations.

The first reporting of outbreaks devolves upon the timber owners, the State or Federal forest rangers, or others who are primarily responsible for the protection of forests. Such work is analogous to that of the forest-fire detection system.

This detection work should be so planned that all valuable forest types subject to bark-beetle outbreaks are given some measure of

inspection for insects each year. This work does not need to be intensive, but at least it should disclose whether trees are dying through any forests tract, and, if so, the probable cause of death, and the extent of the trouble.

If trees are observed to be dying either singly or in groups, they should be examined and the cause of the trouble determined. If there is no evidence of recent forest fires, insects may be suspected as the responsible agents. If so, a closer examination of foliage, twigs, or bark should show what primary insect is involved. The keys and accompanying discussions in the early part of this manual (pp. 28, 58, 60, 95) should be helpful in making this diagnosis. If the cause of death cannot be satisfactorily determined, an expert should be called in or samples of the work and the insects present sent to an entomologist for his study. Samples taken from the middle height of the stem are more apt to include the primary destructive bark beetles than if taken near the ground or in the tops where secondary insects are often most abundant.

Information as to the extent of the damage can be determined by a red-top survey or by strip counts made along roads or trails. The methods to be discussed under "Extensive bark-beetle surveys" are applicable to this preliminary work, but the field work need be only in sufficient detail to give a rough approximation of the location, extent, and intensity of the infestation.

The prompt reporting of the first signs of a bark-beetle outbreak will greatly reduce the ultimate cost of suppression. On most national forests the rangers are required to make at least one annual reconnaissance of their districts and report the conditions as to insect infestations. In this way bark-beetle outbreaks are promptly brought to the attention of the forest officers and a decision can be made as to whether a more extensive survey or immediate control operations are required.

Extensive Bark-Beetle Surveys

After an infestation has been reported by the men on the ground, and before control operations are started, there is usually need for a more complete field examination or extensive survey to determine the intensity, size, and character of the infestation, whether or not control operations are justified, and how large an area must be included to make such work effective.

The importance of obtaining all possible information as to the extent and severity of a bark-beetle outbreak before control measures are started can hardly be overemphasized. Without this information the need and feasibility of control and the magnitude and probable cost of the proposed operation cannot be determined. No project should be undertaken without fairly accurate knowledge of conditions in all surrounding watersheds. Furthermore, the actual operation of control projects cannot be efficiently planned unless such data are available.

One of the first things to be done is to determine the trend of the infestation—whether normal, increasing, or decreasing—and the possibility that natural-control factors will soon become operative. This is done by a thorough study of brood conditions and a comparison of past with current losses. Control measures need not be

applied to normal or rapidly declining infestations, as the operation of natural-control factors in such cases is more effective than artificial measures.

The next step is to make an extensive survey of the area to determine what parts must be included in the control program, the number of trees that will require treatment, and the probable cost of the work. This extensive survey is usually made by experts in forest-insect control who have had experience in estimating bark-beetle losses and planning control campaigns.

The methods to be used in such work will depend on the character of the country, the size of the area involved, the degree of accuracy desired in the results, and the time and money available for the work. The simplest and least expensive type of survey is made by viewing the country from lookout points and making counts along roads. Sample strips run at intervals back and forth across infested areas give a very comprehensive estimate of the amount and distribution of infestation, and where time and money are available these unquestionably furnish the most satisfactory basis of estimates. The cruising of sample plots has its place as a supplement to topographic viewing, and with small units it is often possible actually to survey a rather large percentage of the area in this way. Where large areas of diverse topography include a number of different forest types, several different estimation methods or combinations of methods may be used. In fact, every source of information should be utilized in arriving at the final estimate, and the more survey data at hand the more accurate will be the final result.

The topographic method

The topographic method, or red-top survey, is particularly well adapted to estimating bark-beetle losses over large forested areas of rough topography, where a large part of the forest can be viewed from open valleys, ridges, or lookout points. It is the cheapest and quickest method but is subject to a high degree of error unless supplemented by intensive examinations of sample plots or strips, in which case fairly reliable results can be obtained.

In using this method, the estimator, equipped with binoculars and a topographic map of the area, travels through the area visiting all of the ridges, valleys, or lookout points that can be found. At each selected point the opposite slopes and visible areas are viewed, the red, sorrel, or fading trees counted, and an estimate placed on the map as to the total number of dying or dead trees per acre. Then strips or plots are actually cruised and a ratio determined between the number viewed and the total number acutally found. Also, the relative proportion between newly infested and abandoned trees, all of which have been counted in the general red-top survey, is determined. The total estimate is then corrected by these ratios.

The sample-strip method

The sample-strip method is adapted to estimating bark-beetle losses on flat or gently rolling areas where viewing from a distance is impossible. It is also a more efficient and accurate method and can

be used by inexperienced estimators with a fair degree of accuracy. In order to cover any large area, however, a great many strips must be run, which makes the method more laborious and consequently more time-consuming and expensive.

In using this method, the observer travels through the forest along some routes of known position and length, such as a forest road or trail, but preferably along a section line or compass line, so as to obtain an impartial cross section of the area uninfluenced by the special types of trees which might be encountered along ridges or canyon bottoms. Distances are determined by pacing, or using the known distances between fixed points, such as section corners or topographic features located on accurate maps. Without attempting to blaze or mark the trees, the numbers of fading, sorrel, or red-top trees are counted within a specified distance on either side of the line of travel.

The width of the strip will depend on the density of the forest stand, and should be so chosen that the outer edges will correspond approximately with the average limit of vision within the stand. For open ponderosa pine stands a 10-chain strip (330 feet on each side of the center line) has been found generally satisfactory, but in the heavier stands this often needs to be reduced to an 8-, 5-, or even a 4-chain strip. In lodge pole and western white pine stands, red-top surveys usually are limited to 5-, 4-, 2-, and even 1-chain strips. However, in these types extensive surveys are usually conducted in the fall of the year to determine the number of new attacks, and the old loss represented by the red-top trees is ignored. Since the newly attacked trees are not discolored and can be found only by sighting the pitch tubes, very narrow strips are necessary, and a 1-chain strip (33 feet on each side of the compass line) has been adopted as standard for this work in the northern Rocky Mountain region.

When a red-top strip count includes several ages of infested and recently abandoned trees, it is necessary to examine a representative series of trees, either on a sample strip or on a sample plot, to determine the proportion of the different classes of insect attack and years of infestation which may be represented. A limited amount of intensive work is also necessary to determine the average diameters, heights, and volumes represented by the infested trees. The number of trees counted on the strips multiplied by the number of times the acreage of the strip would be contained in the acreage of the entire area will give the approximate number of trees for the entire unit.

No fixed rule can be given as to the percentage of an infested area that should be covered during an extensive insect survey to obtain a reasonable degree of accuracy. The exactness of the survey will depend on the time and money available and the value of the timber stand under examination. Small units of valuable timber should be covered with a greater refinement of methods and a higher degree of accuracy than an extensive area of heavily infested lodgepole pine. Ordinarily a 5-percent sample of an area should give a reasonably good estimate for control purposes, and on large areas a 1-percent sample is often sufficient.

Bark-Beetle Control Projects

The objective of bark-beetle control is to destroy such a high percentage of the destructive beetles that the aggressive character of an outbreak will be broken and the remaining infestation will be held in check by natural control factors. This involves the treatment of as nearly all of the infested trees within the natural boundaries of an affected area as is feasible within physical limitations; and if migrations threaten from neighboring areas these areas also should be included in the control campaign. Beetle outbreaks, like forest fires, if not promptly taken in hand, are soon apt to increase beyond the practical limitations of artificial control measures.

THE CONTROL UNIT

The size of the area that must be included in any control project in order to obtain satisfactory results is an important point that must be given consideration in making the control plans. The feasibility of a project will frequently depend on the possibility of limiting the control area to a unit that can be covered in a single season with the available man power.

First consideration must be given to the flight habits of the beetles, and the control area should be made large enough to reduce to a minimum the possibility of any large number of beetles flying in from neighboring infested tracts. As far as possible, control units should be bounded by natural barriers, such as high ridges, open valleys, or broad strips of timber of a different type. If these are lacking, then the control area must include all infestation within the flight range of the beetles. This range for practical purposes depends on the intensity of the beetle population in any neighboring area. For instance, in cases where a treated unit is surrounded by scattered infestations of the western pine beetle, reinfestation, in the first year following treatment, has been limited to a zone within a mile of the boundaries. On the other hand, heavy concentrated infestations of the mountain pine beetle have in some cases apparently migrated across 30 miles of open country to reinfest control units.

SPOTTING

The first step in connection with any control project is to locate and mark all infested trees requiring treatment. This is referred to as "spotting" and is one of the most important phases of the work, since the success of any control project depends primarily on finding a high percentage of the infested trees. To accomplish this the forest must be thoroughly and systematically searched by men who know an infested tree when they see one. The work should be begun several days before the treating and should be planned so as to keep it well ahead of the treating work (fig. 88).

The strip method of spotting is the one best adapted to obtaining a systematic 100-percent coverage of the area and is the one now used on nearly all western bark-beetle projects. According to this method, a compass man and from two to four spotters run strips of uniform width back and forth across the area, locate the infested trees, blaze them or mark them, and map their location so that they can be found by the treating crews. With a three-man crew the

compass man, who is usually the chief of the party, runs an accurate compass line, paces the distances traveled, records data relative to trees marked for treatment, constructs a map showing their location, and assists the spotters in the selection of the proper trees for treatment. The two spotters cover strips on the sides of, and parallel to, the course of the compass line, find, blaze, and number the infested trees, and record whatever data are pertinent in regard to them. With a six-man crew there are two spotters on each side of the compass man, and the chief of the party follows behind the crew, working from side to side to assist in the proper marking of the

FIGURE 88.—Ponderosa pines spotted for treatment in Black Hills beetle control, Kaibab National Forest, Ariz.

trees and to prevent any from being missed. Regardless of the organization, the chief spotter is always responsible for the character of the work performed by his crew.

The width of the strip and the number of men in the spotting crew are usually adjusted to the timber type, topography, and density of the infestation. In typical ponderosa pine stands a three-man crew, with each spotter covering a five-chain strip, is the standard practice. This width of strip in the open timber stands of this type permits the spotters to visit and closely examine not only the fading trees but all of those which look suspicious and a high percentage of the green trees as well. On the other hand, in dense lodgepole and white pine stands a one-chain strip is all that a spotter can efficiently cover, since it is necessary to look at the base of every tree, and a six-man crew has been found advantageous in

such timber. When large groups of infested trees are encountered, all spotters assist in marking all trees within the group, even though it extends over into the next strip. The spotter who has had the outside course should always be on the inside during the return trip, as he is familiar with the boundaries of his strip.

The trees selected for treatment are marked in different ways, varying from a blaze to a cloth or card tag tacked upon the tree. When tags are used, it is a good plan to blaze and number the tree on the opposite side, as this permits the relocation of trees in case tags are destroyed. The data placed upon tags will vary for each project, depending on what information is desired. Each tree should be numbered regardless of the type of mark used, so that a check can be maintained on the trees treated. After a tree has been treated the tag is removed, and all tags are turned over to the project superintendent at the close of the day's work and checked against the serial numbers of the trees marked within the area.

BARK-BEETLE SUPPRESSION METHODS

Methods of bark-beetle control must take into consideration the varying habits of the insect species, the trees affected, the locality, and the environmental conditions encountered. Methods effective in one area cannot be used in other areas even against the same insect because of differences in local conditions. Methods suitable for the control of an insect in a tree with thin bark cannot be used in cases where the same species is infesting a tree with thick bark. Differences in latitude and altitude have an important bearing on the success of the sun-curing method, and the differences of type and forest cover will often be a determining factor in the selection of a suitable control measure. It is often necessary to use two or more methods, even on a single project, because of differences in exposure or site conditions, the size of trees infested, or the height of the infestation in the trunk.

Some of the methods that have been of greatest usefulness in the past are the following:

(1) Burning methods; in which the trees are felled, partly peeled, and burned; felled and rolled into decks and burned; or burned standing.

(2) Peeling methods; in which the bark is removed from the tree, and the insects exposed to predators or left to die through exposure to the sun's heat.

(3) Solar-heat method; in which the trees are felled and the insects killed by the sun's heat without peeling the bark from the logs.

(4) Submerging infested logs in water and drowning the insects.

(5) Removing the infested trees from the woods through logging operations before the insects have had time to emerge and escape.

Since most of the destructive bark beetles confine their attacks to a few species of trees, control can be carried out by treating just the affected host trees.

The fell-peel-burn method

The fell-peel-burn method is one of the oldest for bark-beetle control, yet one which is still used in the suppression of outbreaks of the western pine beetle and related species, the larvae of which burrow into the outer bark and are not exposed when the bark is peeled from the tree.

FIGURE 89.—Felling bark-beetle-infested ponderosa pines is the first step in their treatment.

In this method the infested trees are first felled (fig. 89), either up or down hill but away from new growth or heavy patches of brush—never across the slope of the hill, if this can be avoided, since a broad flame is more difficult to control than a narrow one. Then the bark is peeled from the top half of the fallen trunk for as far as the infestation extends, piled along the sides, and set on

fire (fig. 90). The flames creep under the log and scorch the unpeeled bark. If it is desired to dispose of the brush at the same time, the limbs and top are cut off and piled back over the trunk. If this would make too large and dangerous a fire, this material can be left out and burned at a later time or spread on the ground to decay. As a fire precaution, a fire line is constructed by scraping away all the litter and duff down to the mineral soil for a width of about 3 feet and completely encircling the tree. In treating a tree infested with the western pine beetle it is desirable to leave the stump

FIGURE 90.—After partial peeling, trees infested by the western pine beetle are burned.

and the duff around it unburned in order to protect the beneficial clerids in their pupal cells, which are usually concentrated around the base of the tree.

The fire should be allowed to consume the infested bark, but should not be so large as to make it difficult to control. In wet weather pitch will have to be supplied to burn the bark sufficiently, while in dry weather all tops, limbs, and even needles will have to be thrown outside of the fire line in order to keep the fire from becoming too large. In wet weather the burning should be with the wind and uphill in order to create enough draft to consume the bark; but in dry weather this should never be done, but the burn-

ing should be downhill and against the wind so that the fire can be controlled. Burning, if done by experienced men, can be handled without injury to the forest. Ordinarily the fire is not hot enough to burn the logs, and if at all accessible they can be used for lumber if taken out within a year or two.

The fell-deck-burn method

The fell-deck-burn method is one of the most economical control methods and is particularly useful in the control of bark beetles infesting trees of small diameter (fig. 91) such as small ponderosa pine, lodgepole pine, or western white pine, infested with the mountain pine beetle or Black Hills beetle, especially where large groups of trees are infested. By using tractors or teams even the larger trees can be handled for treatment by this method.

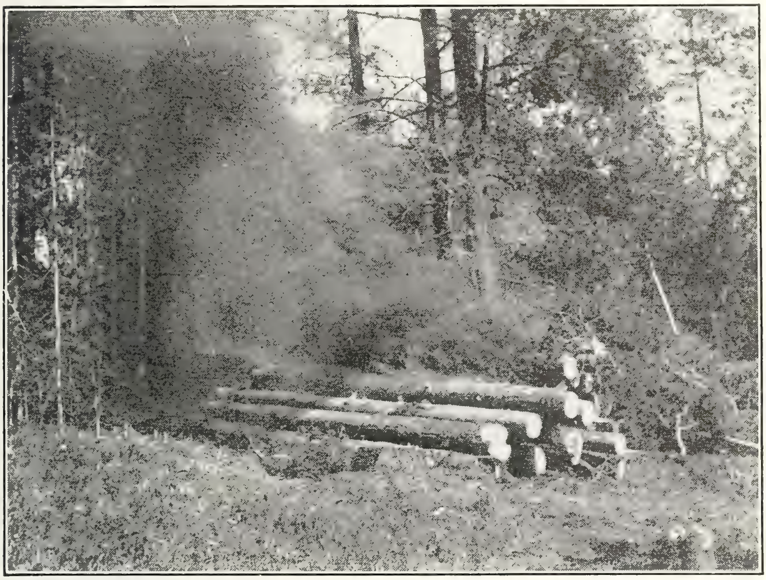

FIGURE 91.—Burning in decks is an economical method of treating bark beetle-infested trees of small diameter.

The trees are felled usually in one direction, and then by using peavies, are hand-rolled into piles, or dragged by horses or tractors into openings where they can be bunched into large decks. No peeling is necessary, except occasionally on the outer surfaces of the outer logs. The whole pile is then fired and usually is completely consumed.

This is a very satisfactory method where it can be used and is not only more economical than the fell-peel-burn method but leaves the forest free from the fire hazard of fallen logs and piles of brush. This method also permits the control work to start before the close of the fire season in the fall since the piles can be prepared, and the burning done at a later date. Since the burning of decked logs throws out a terrific heat, the size of the piles should be adjusted to

the amount of space available so that neighboring living trees will not be injured. If this precaution is not taken, the scorched trees may draw in additional infestation and more or less nullify the effects of the control work.

The oil-burning method

Recent control technique has developed an economical method of killing bark beetles in thin-bark trees, such as lodgepole pine, by spraying the bark with fuel oil, firing it, and letting the bark be scorched deeply enough so that the beetles will be killed by the heat. The trees may be either felled and burned or burned in a standing position.

A fuel oil is used that has a high caloric content and burns evenly and without too quick a flash. An explosive oil burns too quickly to give good heat penetration. For burning standing trees a light oil of gravity 32° to 34° Baumé and a flash point of 160° F. has given the best results. For burning trees on the ground ordinary fuel oil with a gravity of 27°+ Baumé and a flash point of 225° F. has been found most satisfactory because of its slower burning, greater heat penetration, and lower cost. In either case from one-half to three-fourths of a gallon is required to burn the average lodgepole pine. The oil is applied with a hand pump through a long nozzle.

With the burning-standing method, the oil is sprayed as high on the bole of the tree as the equipment will permit, about 30 feet at present, and the entire top of the tree is "crowned out" with fire. The treatment is effective only to the height of the burn, and unless the bole is thoroughly scorched as high as to a 6- or 8-inch diameter, which is usually the upper limit of infestation, the tree must be felled and the scorched portion burned with additional oil. When lodgepole pine bark has been adequately burned to kill the beetles underneath, the bark flakes will curl and show white on the edges. Frequently when this method is used, the spotting and treating are performed at the same time. A pack train carrying the pressure sprayers, oil, and felling tools follows the spotting crew, and infested trees are treated wherever they are found. This method is an economical one, and costs have averaged between 68 cents and $1.05 per tree. While the method is effective in ordinary weather it cannot be used on windy or stormy days, and during dry or windy weather great care must be used to avoid serious conflagrations. This method is limited to the treatment of thin-barked trees such as lodgepole pine, to trees of moderate height that can be burned as high up as the infestation, and to situations where the fire hazard is not too great.

Lodgepole pine growing in dark woods or in dense thickets of underbrush where the sun-curing method is not effective, or tall trees which cannot be successfully treated in the standing position, can be felled and burned with oil in places where decking and burning in piles would not be feasible. A slow-burning fuel oil is used, and the fire is carried along and confined to the bole of the tree by spraying on oil from a hand pump. Two men follow behind the fireman and quickly extinguish any fire left on the tree or starting on the ground. It is surprising in what hazardous areas this method can be used without difficulty.

Penetrating oils

Recent experiments in California have developed some petroleum oils that, when sprayed on the trunk of pine trees, will penetrate the bark and kill the pine beetle broods beneath. The most effective oils developed to date are those of the distillate grade carrying as much naphthalene as can be taken in solution. These when applied to infested ponderosa pine bark at the rate of about 4 ounces per square foot will give mortalities ranging from 50 to 90 percent. Oils of this type, however, are effective only when temperatures are above 60° F. and cannot be used at all when the bark is wet. This method of control is still in the experimental stages, with the possibility that it may be useful in treating infested trees during the summer months on recreational areas or late in the spring and early in the fall when the fire hazard is too great to permit burning.

The peeling method

The peeling method can be used in the control of those bark beetles that, in the immature stages, work between the bark and the wood and die of exposure when the bark is removed, and is especially applicable to moderately thick-barked trees that are easily peeled. It has been used extensively in the control of the Black Hills beetle in ponderosa pine of the Rocky Mountain region and in the control of the mountain pine beetle in western white pine. It has the important advantage of involving no immediate fire risk and is cheaper than the burning method for the treatment of isolated trees less than 30 inches in diameter. If the bark tends to adhere to the wood, however, peeling is a very slow, tedious process and in the spring will not destroy overwintering adults, new adults, or pupae in the last stages of development. In general, it is more expensive than the burning method, especially for the treatment of trees in groups. Moreover, it leaves a mass of slash and crisscrossed logs in the woods that seriously increases the fire hazard.

In carrying out this method, the infested trees are felled across logs or other felled trees to hold them off the ground, and then all of the infested bark is peeled with an ax or barking spud and allowed to drop to the ground where ants, rodents, and exposure dispose of the immature bark beetles (fig. 92). In some rare cases, where all of the infestation is within 20 feet of the ground, the barking has been done with long-handled barking spuds without felling the trees. In such cases, of course, the work can be done more cheaply than where felling the trees becomes necessary.

Peeling and spreading bark

A modification of the peeling method, involving the spreading of the bark where it will receive the direct rays of the sun, has been used with a fair degree of success in the control of the western pine beetle and is applicable to the treatment of ponderosa pines infested with broods of this species late in the spring or in the summer in places where burning would be dangerous.

In this method the tree is felled across a log so as to keep a large part of the trunk off the ground, and the bark is peeled and spread

out in the open where it will receive the direct rays of the sun. To be effective it is necessary to have summer air temperatures of 85° F. or more in order to produce fatal temperatures of 115° to 120° in the bark. The bark must be very carefully spread and must not be left in the shade of other slabs or trees. On north slopes or in canyons it must be carried out to an opening or propped against rocks or trees in order that the sun's rays may strike it at an angle of not less than 45°.

FIGURE 92.—Peeling western white pines infested by bark beetles by means of spuds.

It can be readily seen that the method is tedious and expensive and of limited application. Effective temperatures do not always prevail during the control season, especially at high altitudes and on northern exposures. The method also requires a greater attention to detail than can ordinarily be expected from the average workman. Summer control work in which this method is used has not proved very effective, and the method has lost favor in recent years.

The solar-heat method

The solar heat or sun-curing method (*69*) is particularly applicable to the control of bark beetles, other than the engraver beetles or flatheaded borers, that attack thin-barked trees of small diameter, such as lodgepole pine, especially those growing in open stands and and in areas where the deck-burning method is objectionable.

In this method, trees are felled in a north-and-south direction parallel to one another and never crisscross as in the peeling method.

They are completely limbed and the brush cleared away so that the logs will receive direct sunlight. After a few day's exposure with air temperatures of 80° F. or more all of the bark beetles on the top half of the logs will have been killed. Then the men return and with peavies turn the logs completely over so that the other side will be exposed.

This method has been very effectively used for several years in control of the mountain pine beetle in Crater Lake National Park. It has the advantage of being much cheaper than either the peeling or burning methods; and in crowded stands it avoids the scorching of adjacent trees, and thus does not set up influences attractive to the beetles which would favor reinfestation, as so often happens when the logs are burned. The disadvantages are that considerable slash is left in the woods, and the method cannot be used in the shade of dense stands, on cold north slopes, or in localities where air temperatures during the control season are less than 80° F.

Submerging the infested logs

Many years ago A. D. Hopkins advocated the submerging of infested logs as a means of destroying bark beetles where the infested trees could be cut and placed in a mill pond. Recent experiments have shown that infested logs must be submerged for at least 6 weeks in order to destroy the broods of the western pine beetle. In any shorter period than this the beetle's development is simply retarded. Also, the beetles in the portion of the logs not covered by water are unhampered in their development and are free to emerge and escape. So far this method has been tried only in an experimental way, but it has possibilities, where applicable, and sometime may be of value in connection with a control project.

The trap-tree method

A method of bark-beetle control that has been used in Europe with apparent success consists in felling injured, weakened, or suppressed, noncommercial trees in accessible locations as attractive baits for bark-beetle broods, and then destroying them after the beetles have entered the bark. The method has been tried on numerous projects and on rather an extensive scale in California and southern Oregon in the control of the western pine beetle, but with little success. Although beetles are attracted to the traps, these fail to protect the standing trees in the vicinity, and frequently the trap tree acts as a source of attraction to bring in bark beetles that kill groups of adjacent standing trees. Moreover, the trap trees have always failed to absorb any large proportion of the beetles in their area, and hence the method has lost favor as an effective or economical control measure. It may, however, prove of value in the control of other species, particularly in cases where the trap logs can be removed and utilized.

Bark-beetle control by logging

Where the infestations are in accessible tracts of valuable timber, the cutting and salvage of the infested trees through logging operations is an effective and economical method of control. This method

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was first advocated by Hopkins for the control of *Dendroctonus* beetles. He proposed that the infested logs be removed from 20 to 50 miles from the forest so that the beetles emerging from them would find no trees to attack. Often this method has been followed unwittingly by logging operators who have cut infested trees and sent them to distant mills or burned the slabs; and this, together with the removal of beetles in recently felled green logs, explains the absence of insect-killed trees around many going logging operations. Of late years this method has come more and more into favor with the opening up of forest tracts and the development of truck logging, which has made possible the removal of scattered infested trees at comparatively low costs (*53a*).

This method serves the dual purpose of controlling the bark beetles and salvaging timber that otherwise would be completely worthless within a short time. Where the method can be used it is economical and sometimes can be carried out with a small immediate profit from the operation in addition to suppressing the beetle outbreak. Even if the logging operation is carried out at a loss of from $1 to $2 per thousand board feet of timber, it is better than spending $3 or $4 a thousand feet to fell the trees and burn them or leave them in the woods, as is the case with the usual control operations. The reduction of infestation by either method will be the same.

In inaccessible areas the method cannot be applied except at a cost in excess of that of the ordinary control methods, and of course cannot be used in the control of bark beetles attacking unmerchantable species of trees whose chief value lies in the protection of watersheds or as a forest cover in parks and recreational areas. Moreover, bark beetles introduce blue stains which discolor the sapwood before there is any possibility of salvage, and thus reduce the value of the material. In ponderosa pine areas it rarely pays to salvage tops or trees less than 22 inches in diameter, and such unmerchantable material must be burned to complete the control operation. Because of immediate blue staining the value of the logs taken out of the woods is reduced approximately 50 percent below that of green logs, so returns from the operation must be computed on that basis. If the method is to be effective, the beetles on an entire unit must be destroyed in a single season, which means that the logging operation must frequently be extended over a very large area. This is often difficult, so logging must be supplemented in many cases by the ordinary control methods.

MAINTENANCE CONTROL

One season's treatment of an area will rarely be sufficient to bring an outbreak under control. Even with the most careful spotting and treatment some infestation will be missed that will give rise to new infestation the following year. A follow-up program, or maintenance control, is therefore necessary until the normal balance is restored and the bark beetles reduced to an endemic status.

With infestations of the mountain pine beetle, unless migrations occur, a 75-percent reduction is usually obtained following the first season's work, and one or two seasons of maintenance work will usually bring the epidemic under complete control. In western pine

beetle control, reductions of more than 50 percent are rarely obtained in one season, and the work has to be repeated for several seasons until the resistance of the stand has improved through removal of beetle-susceptible trees or until the trees are better able to resist attacks. In fact, during long periods of drought and lowered tree resistance, almost continuous work may be necessary to hold the beetle population down to reasonable limits.

In this work special consideration must be given to the natural-control factors and an effort made to favor their effectiveness while reducing the population of the destructive species. The avoidance of burning around stumps where predators congregate, the saving of certain infested trees to permit multiplication of the beneficial parasitic insects present, and the improvement of stand resistance are some of the ways in which natural control may be encouraged (pp. 169, 172, 173).

When Control Measures Are Advisable

When the natural balance in a forest is disturbed and an outbreak of bark beetles threatens to destroy a large number of valuable trees, the application of direct control measures (*27*) is advisable provided effective methods are available and the value of the timber that can be protected will justify the expense of the work. Control measures are expensive and unless the timber is valuable enough from the commercial, watershed-protection, or aesthetic standpoints to warrant the cost of control measures, it is best to allow Nature to bring the epidemic under control in her own way.

To reach a decision certain data must be obtained. In the first place, the primary agency responsible for the death of the trees should be determined. If trees are dying because of drought, fire injury, flooding, or other causes, there is obviously little use to dispose of the insects, which may be only the final cause of their death. Nor is it wise to attempt to exterminate native bark beetles present on an area under normal conditions. Only when the natural-control factors have been disturbed and an outbreak threatens should artificial measures be taken.

In the second place, it must be determined whether effective and economical control measures are available. In some cases, because of the habits of the beetles, no satisfactory methods of control have been devised. For instance, the control of the white fir engraver beetles through burning the bark of dying trees is of little value since a large number of these insects may continue to breed in perfectly green trees, causing only local damage. Moreover, the control measures must not be so expensive as to exceed the value of timber that might be saved.

And lastly, it is most important that cooperation be secured from all owners in the infested area so that the control campaign can cover all of the contiguous infested territory in a single season. Small tracts cannot be successfully cleaned up if neighboring or intermingled tracts are left untreated.

Control Costs and Probable Results

The cost of control work varies with the size and type of timber, the method of treatment, the intensity of the infestation, the rough-

ness of the terrain, the accessibility of the area, the current cost of labor, and so many other factors that it is impossible to give any specific costs which might apply to a given situation. Some idea of the approximate cost of the work, however, may be obtained from experience gained during the decade from 1921 to 1930.

In the ponderosa pine region of California, Oregon, and Washington the control of the western pine beetle cost on an average about $4 per treated tree, with the cost in some cases dropping as low as $1.75 per tree. In the control of the Black Hills beetle in ponderosa pine of the Rocky Mountain region the cost per tree averaged about $1.50 with some costs as low as 75 cents per tree.

The control of the mountain pine beetle in lodgepole pine forests, where either the solar-heat method or the fell-deck-burn method was used, cost on the average from 50 cents to $1 per treated tree, depending largely on the intensity of the infestation. Under similar conditions the solar-heat method is the cheaper of the two.

The control of mountain pine beetle infestations in western white pine cost about $4.50 per tree, and in sugar pine, on account of its very large size, the costs sometimes amounted to as much as $16 per tree.

For the treatment of a few scattered trees around summer homes or in inaccessible areas the costs will run higher than on large-scale projects.

Bark-beetle control work has been in progress in western forests since 1911, and the results of this work have indicated rather definitely what can be expected in the control of some of the more important species (*27*).

Wherever bark beetles have been primarily responsible for the death of trees, the application of control measures has resulted in reducing the infestation or in restoring the natural balance so as to bring the outbreak under control. With such aggressive tree-killing species as the mountain pine beetle and the Black Hills beetle, control work has been very effective in quickly suppressing outbreaks wherever a high percentage of the infested territory could be covered in a single season and the results were not nullified by migrations from distant areas. Western pine beetle epidemics have so frequently been partly dependent upon a weakened condition of the host tree that the results from control have not been so clear-cut. Infestations have been reduced, but unless the work is continued or conditions bring about improved tree resistance, the reductions brought about by control efforts are difficult to maintain.

At best, remedial bark-beetle control is only a temporary expedient, or a method of suppressing outbreaks that have been brought about through some interruption, disturbance, or failure of the biological balance. The only permanent protection is through the management of forest properties so as to maintain the natural balance, or if this is broken by forces beyond man's control, to be able to salvage the killed timber quickly enough to prevent excessive loss.

LITERATURE CITED

(1) Annand, P. N.
1928. A CONTRIBUTION TOWARD A MONOGRAPH OF THE ADELGINAE (PHYLLOXERIDAE) OF NORTH AMERICA. 146 pp., illus. (Stanford Univ. Pub., Univ. Ser., Biol. Sci. v. 6, no. 1).

(2) Balch, R. E.
1932. THE FIR TUSSOCK MOTH (HEMEROCAMPA PSEUDOTSUGATA MCD.). Jour. Econ. Ent. 25: 1143–1148.

(3) ———
1932. THE BLACK-HEADED BUDWORM. Canada Dept. Agr. Spec. Circ. 4 pp., illus.

(4) Banks, N., and Snyder, T. E.
1920. A REVISION OF THE NEARCTIC TERMITES, WITH NOTES ON BIOLOGY AND GEOGRAPHIC DISTRIBUTION. U. S. Natl. Mus. Bull. 108, 228 pp., illus.

(4a) Beal, J. A.
1934. RELATION OF AIR AND BARK TEMPERATURES OF INFESTED PONDEROSA PINES DURING SUBZERO WEATHER. Jour. Econ. Ent. 27: 1132–1139, illus.

(5) Blackman, M. W.
1928. THE GENUS PITYOPHTHORUS EICHH. IN NORTH AMERICA. A REVISIONAL STUDY OF THE PITYOPHTHORI, WITH DESCRIPTIONS OF TWO NEW GENERA AND SEVENTY-ONE NEW SPECIES. N. Y. State Col. Forestry, Syracuse Univ., Tech. Pub. 25, 212 pp., illus.

(6) ———
1931. THE BLACK HILLS BEETLE (DENDROCTONUS PONDEROSAE HOPK.). N. Y. State Col. Forestry, Syracuse Univ., Tech. Pub. 36, 97 pp., illus.

(7) Brunner, J.
1914. THE SEQUOIA PITCH MOTH, A MENACE TO PINE IN WESTERN MONTANA. U. S. Dept. Agr. Bull. 111, 11 pp., illus.

(8) ———
1915. DOUGLAS FIR PITCH MOTH. U. S. Dept. Agr. Bull. 255, 23 pp., illus.

(9) ———
1915. THE ZIMMERMAN PINE MOTH. U. S. Dept. Agr. Bull. 295, 12 pp., illus.

(10) Burgess, A. F., and Crossman, S. S.
1927. THE SATIN MOTH, A RECENTLY INTRODUCED PEST. U. S. Dept. Agr. Bull. 1469, 23 pp., illus.

(11) Burke, H. E.
1905. BLACK CHECK IN WESTERN HEMLOCK. U. S. Dept. Agr., Bur. Ent. Circ. 61, 10 pp., illus.

(12) ———
1917. FLAT-HEADED BORERS AFFECTING FOREST TREES IN THE UNITED STATES. U. S. Dept. Agr. Bull. 437, 8 pp., illus.

(13) ———
1919. BIOLOGICAL NOTES ON SOME FLATHEADED BARKBORERS OF THE GENUS MELANOPHILA. Jour. Econ. Ent. 12: 105–108.

(14) ———
1928. THE WESTERN CEDAR POLE BORER OR POWDER WORM. U. S. Dept. Agr. Tech. Bull. 48, 16 pp., illus.

(15) ———
1929. THE PACIFIC FLATHEAD BORER. U. S. Dept. Agr. Tech. Bull. 83, 36 pp., illus.

(16) ———
1932. TWO DESTRUCTIVE DEFOLIATORS OF LODGEPOLE PINE IN THE YELLOWSTONE NATIONAL PARK. U. S. Dept. Agr. Circ. 224, 20 pp., illus.

(17) Burke, H. E., Hartman, R. D., and Snyder, T. E.
1922. THE LEAD-CABLE BORER OR "SHORT-CIRCUIT BEETLE" IN CALIFORNIA. U. S. Dept. Agr. Bull. 1107, 56 pp., illus.
(18) ——— and Herbert, F. B.
1920. CALIFORNIA OAK WORM. U. S. Dept. Agr. Farmers' Bull. 1076, 14 pp., illus.
(19) Chamberlin, W. J.
1918. BARK-BEETLES INFESTING THE DOUGLAS FIR. Oreg. Agr. Expt. Sta. Bull. 147, 40 pp., illus.
(20) ———
1920. THE WESTERN PINE BARK-BEETLE, A SERIOUS PEST OF WESTERN YELLOW PINE IN OREGON. Oreg. Agr. Expt. Sta. Bull. 172, 30 pp., illus.
(21) Craighead, F. C.
1915. CONTRIBUTIONS TOWARD A CLASSIFICATION AND BIOLOGY OF THE NORTH AMERICAN CERAMBYCIDAE, LARVAE OF THE PRIONINAE. U. S. Dept. Agr. Rept. 107, 24 pp., illus.
(22) ———
1919. PROTECTION FROM THE LOCUST BORER. U. S. Dept. Agr. Bull. 787, 12 pp., illus.
(23) ———
1922. EXPERIMENTS WITH SPRAY SOLUTIONS FOR PREVENTING INSECT INJURY TO GREEN LOGS. U. S. Dept. Agr. Bull. 1079, 11 pp.
(24) ———
1923. NORTH AMERICAN CERAMBYCID LARVAE. A CLASSIFICATION AND THE BIOLOGY OF NORTH AMERICAN CERAMBYCID LARVAE. Canada Dept. Agr. Ent. Branch Bull. (n. s.) 27, 238 pp., illus.
(25) ———
1925. RELATION BETWEEN MORTALITY OF TREES ATTACKED BY THE SPRUCE BUDWORM (CACOECIA FUMIFERANA CLEM.) AND PREVIOUS GROWTH. Jour. Agr. Research 30: 541–555, illus.
(26) ——— and Hofer, G.
1921. PROTECTION OF MESQUITE CORDWOOD AND POSTS FROM BORERS. U. S. Dept. Agr. Farmers' Bull. 1197, 12 pp., illus.
(27) ——— Miller, J. M., Evenden, J. C., and Keen, F. P.
1931. CONTROL WORK AGAINST BARK BEETLES IN WESTERN FORESTS AND AN APPRAISAL OF ITS RESULTS. Jour. Forestry 29: 1001–1018.
(28) Cushman, R. A.
1927. THE PARASITES OF THE PINE TIP MOTH, RHYACIONIA FRUSTRANA (COMSTOCK). Jour. Agr. Research 34: 615–622, illus.
(29) Davis, J. J.
1924. COMMON WHITE GRUBS. U. S. Dept. Agr. Farmers' Bull. 940 (rev.), 30 pp., illus.
(30) DeLeon, D., Bedard, W. D., and Terrell, T. T.
1934. RECENT DISCOVERIES CONCERNING THE BIOLOGY OF THE MOUNTAIN PINE BEETLE AND THEIR EFFECTS ON CONTROL IN WESTERN WHITE PINE STANDS. Jour. Forestry 32: 430–436, illus.
(31) Evenden, J. C.
1926. THE PINE BUTTERFLY, NEOPHASIA MENAPIA FELDER. Jour. Agr. Research 33: 339–344, illus.
(32) Felt, E. P.
1918. KEY TO AMERICAN INSECT GALLS. N. Y. State Mus. Bull. (1917) 200, 310 pp., illus.
(33) Fracker, S. B., and Granovsky, A. A.
1928. AIRPLANE DUSTING TO CONTROL THE HEMLOCK SPANWORM. Jour. Forestry 26: 12–33, illus.
(34) Garman, H.
1915. THE LOCUST BORER (CYLLENE ROBINIAE) AND OTHER INSECT ENEMIES OF THE BLACK LOCUST. Ky. State Forester Bien. Rept. 2: [32]–63, illus.
(35) Gillette, C. P., and Langford, G. S.
1925. CONTROL OF SOME SCALE INSECTS INFESTING COLORADO TREES AND SHRUBS. Colo. State Ent. Circ. 46, 14 pp., illus.
(36) Graham, S. A.
1922. THE RED TURPENTINE BEETLE IN ITASCA PARK. Minn. State Ent. Rept. 19: 15–21.

(37) GRAHAM, S. A.
1922. SOME ENTOMOLOGICAL ASPECTS OF THE SLASH DISPOSAL PROBLEM. Jour. Forestry 20: 437–447.

(38) ——— and BAUMHOFER, L. G.
1927. THE PINE TIP MOTH IN THE NEBRASKA NATIONAL FOREST. Jour. Agr. Research 35: 323–333, illus.

(39) HEINRICH, C.
1923. REVISION OF THE NORTH AMERICAN MOTHS OF THE SUBFAMILY EUCOSMINAE OF THE FAMILY OLETHREUTIDAE. U. S. Natl. Mus. Bull. 123, 298 pp., illus.

(40) HERBERT, F. B.
1920. WESTERN TWIG PRUNERS. Jour. Econ. Ent. 13: 360–363.

(41) ———
1920. CYPRESS BARK SCALE. U. S. Dept. Agr. Bull. 838, 22 pp., illus.

(42) ———
1924. THE EUROPEAN ELM SCALE IN THE WEST. U. S. Dept. Agr. Bull. 1223, 20 pp., illus.

(43) HOFER, G.
1920. THE ASPEN BORER AND HOW TO CONTROL IT. U. S. Dept. Agr. Farmers' Bull. 1154, 11 pp., illus.

(44) HOPKINS, A. D.
1903. INSECT ENEMIES OF THE REDWOOD. U. S. Dept. Agr., Bur. Forestry Bull. 38: 32–40, illus.

(45) ———
1906. THE LOCUST BORER. (CYLLENE ROBINIÆ FORST.) U. S. Dept. Agr., Bur. Ent. Bull. 58: 1–16, illus.

(46) ———
1909. PRACTICAL INFORMATION ON THE SCOLYTID BEETLES OF NORTH AMERICAN FORESTS. I. BARK BEETLES OF THE GENUS DENDROCTONUS. U. S. Dept. Agr., Bur. Ent. Bull. 83, pt. 1, 169 pp., illus.

(47) ———
1910. INSECT INJURIES TO FOREST PRODUCTS. U. S. Dept. Agr., Bur. Ent. Circ. 128, 9 pp.

(48) ———
1911. CONTRIBUTIONS TOWARDS A MONOGRAPH OF THE BARK-WEEVILS OF THE GENUS PISSODES. U. S. Dept. Agr., Bur. Ent. Bull. (tech. ser.) 20: 1–68, illus.

(49) ——— and SNYDER, T. E.
1917. POWDER-POST DAMAGE BY LYCTUS BEETLES TO SEASONED HARDWOODS. U. S. Dept. Agr. Farmers' Bull. 778, 20 pp., illus.

(49a) HOPPING, G. R.
1928. THE WESTERN CEDAR BORER (TRACHYKELE BLONDELI MARS.) Can. Dept. Agr. Pamphlet 94 (n. s.) 17 pp., illus.

(49b) ———
1934. AN ACCOUNT OF THE WESTERN HEMLOCK LOOPER (ELLOPIA SOMNIARIA HULST.) ON CONIFERS IN BRITISH COLUMBIA. Sci. Agr. 15 (1): 12–29, illus.

(49c) ——— and JENKINS, J. H.
1933. THE EFFECT OF KILN TEMPERATURES AND AIR-SEASONING ON AMBROSIA INSECTS (PINWORMS). Can. Dept. Int. Forest Ser. Circ. 38, 14 pp., illus.

(50) HOPPING, R.
1921. THE CONTROL OF BARK-BEETLE OUTBREAKS IN BRITISH COLUMBIA. Canada Dept. Agr., Ent. Branch Circ. 15, 15 pp., illus.

(51) HOWARD, L. O.
1917. THE PRACTICAL USE OF THE INSECT ENEMIES OF INJURIOUS INSECTS. U. S. Dept. Agr. Yearbook 1916: 273–288, illus.

(52) HUBBARD, H. G.
1897. THE AMBROSIA BEETLES OF THE UNITED STATES. U. S. Dept. Agr., Div. Ent. Bull. (n. s.) 7: 1–30, illus.

(53) HYSLOP, J. A.
1915. WIREWORMS ATTACKING CEREAL AND FORAGE CROPS. U. S. Dept. Agr. Bull. 156, 34 pp. illus.

(53a) KEEN, F. P.
1931. PINE BEETLE CONTROL COSTS REDUCED THROUGH LOGGING AND SALVAGE. U. S. Dept. Agr. Yearbook 1931, pp. 428–430, illus.

(54) KEEN, F. P.
1932. THE CONTROL OF HEMLOCK LOOPERS BY AIRPLANE DUSTING. Jour. Forestry 30: 506–507.

(55) ———
1936. RELATIVE SUSCEPTIBILITY OF PONDEROSA PINES TO BARK-BEETLE ATTACK. Jour. Forestry 34: 919–927, illus.

(55a) ——— and FURNISS, R. L.
1937. EFFECTS OF SUBZERO TEMPERATURES ON POPULATIONS OF WESTERN PINE BEETLE DENDROCTONUS BREVICOMIS LEC. Jour. Econ. Ent. 30: 482–504, illus.

(56) KOFOID, C. A., LIGHT, S. F., HORNER, A. C., RANDALL, M., HERMES, W. B., and BOWE, E. E.
1934. TERMITES AND TERMITE CONTROL. Ed. 2, rev., 795 pp., illus. Berkeley, Calif.

(56a) MATHERS, W. G.
1935. TIME OF FELLING IN RELATION TO INJURY FROM AMBROSIA BEETLES OR PIN WORMS. Brit. Col. Lumberman 19 (8): 14.

(57) MATHESON, R.
1917. THE POPLAR AND WILLOW BORER. N. Y. (Cornell) Agr. Expt. Sta. Bull. 388, pp. 457–483, illus.

(58) MILLER, J. M.
1914. INSECT DAMAGE TO THE CONES AND SEEDS OF PACIFIC COAST CONIFERS. U. S. Dept. Agr. Bull. 95, 7 pp., illus.

(59) ———
1915. CONE BEETLES: INJURY TO SUGAR PINE AND WESTERN YELLOW PINE. U. S. Dept. Agr. Bull. 243, 12 pp., illus.

(60) ———
1916. OVIPOSITION OF MEGASTIGMUS SPERMOTROPHUS IN THE SEED OF DOUGLAS FIR. Jour. Agr. Research 6: 65–68, illus.

(61) ———
1930. THE RELATION OF WINDFALLS TO BARK-BEETLE EPIDEMICS. 4th Internatl. Cong. Ent. 1928, Trans. 1: 992–1002, illus.

(62) ———
1931. HIGH AND LOW LETHAL TEMPERATURES FOR THE WESTERN PINE BEETLE. Jour. Agr. Research 43: 303–321, illus.

(63) ———
1933. A RECORD OF WINTER KILL OF WESTERN PINE BEETLE IN CALIFORNIA, 1932. Jour. Forestry 31: 443–446.

(64) ——— and PATTERSON, J. E.
1927. PRELIMINARY STUDIES ON THE RELATION OF FIRE INJURY TO BARK-BEETLE ATTACK IN WESTERN YELLOW PINE. Jour. Agr. Research 34: 597–613, illus.

(65) PACKARD, C. M., and THOMPSON, B. G.
1921. THE RANGE CRANE-FLIES IN CALIFORNIA. U. S. Dept. Agr. Circ. 172, 8 pp., illus.

(66) PATTERSON, J. E.
1921. LIFE HISTORY OF RECURVARIA MILLERI, THE LODGEPOLE PINE NEEDLE-MINER, IN THE YOSEMITE NATIONAL PARK, CALIFORNIA. Jour. Agr. Research 21 (3): 127–142, illus.

(67) ———
1927. THE RELATION OF HIGHWAY SLASH TO INFESTATIONS BY THE WESTERN PINE BEETLES IN STANDING TIMBER. U. S. Dept. Agr. Tech. Bull. 3, 10 pp., illus.

(68) ———
1929. THE PANDORA MOTH, A PERIODIC PEST OF WESTERN PINE FORESTS. U. S. Dept. Agr. Tech. Bull. 137, 20 pp., illus.

(69) ———
1930. CONTROL OF THE MOUNTAIN PINE BEETLE IN LODGEPOLE PINE BY THE USE OF SOLAR HEAT. U. S. Dept. Agr. Tech. Bull. 195, 20 pp., illus.

(70) PERSON, H. L.
1928. TREE SELECTION BY THE WESTERN PINE BEETLE. Jour. Forestry 26: 564–578, illus.

(71) ROHWER, S. A.
1913. TECHNICAL PAPERS ON MISCELLANEOUS FOREST INSECTS. VI. CHALCIDS INJURIOUS TO FOREST-TREE SEEDS. U. S. Dept. Agr., Div. Ent. Tech. Ser. 20 (pt. 6): 157–163.

(71a) Rust, H. J.
1935. The role of predatory agents in the artificial control of the mountain pine beetle. Jour. Econ. Ent. 28: 688–691, illus.
(71b) Salman, K. A.
1935. The effects of attack by Pissodes terminalis Hopping on lodgepole pine in California. Jour. Econ. Ent. 28: 496–497.
(72) St. George, R. A.
1929. Protection of log cabins, rustic work, and unseasoned wood from injurious insects. U. S. Dept. Agr. Farmers' Bull. 1582, 20 pp., illus.
(73) Snyder, T. E.
1924. Tests of methods of protecting woods against termites or white ants. A progress report. U. S. Dept. Agr. Bull. 1231, 16 pp., illus.
(74) ———
1926. Preventing damage by Lyctus powder-post beetles. U. S. Dept. Agr. Farmers' Bull. 1477, 13 pp., illus.
(75) ———
1926. Preventing damage by termites or white ants. U. S. Dept. Agr. Farmers' Bull. 1472, 22 pp., illus.
(76) ———
1927. Defects in timber caused by insects. U. S. Dept. Agr. Bull. 1490, 47 pp., illus.
(77) ———
1933. Injury to buildings by termites. U. S. Dept. Agr. Leaflet 101, 8 pp., illus.
(78) Swaine, J. M.
1913. Tent caterpillars. Canada Dept. Agr., Div. Ent. Circ. 1, 14 pp., illus.
(79) ———
1918. Canadian bark-beetles, part II. A preliminary classification, with an account of the habits and means of control. Canada Dept. Agr., Ent. Branch Bull. 14, 143 pp., illus.
(80) ———
1925. The factors determining the distribution of North American bark-beetles. Canada Ent. 57: [261]–266.
(81) ———
1930. Airplane dusting operations for the control of defoliating insects. Canada Dept. Natl. Defense, Civil Aviation and Civil Govt. Air Oper. Rept. 1929, 16 pp., illus.
(82) ——— Craighead, F. C., and Bailey, I. W.
1924. Studies on the spruce budworm (Cacoecia fumiferana Clem.). Canada Dept. Agr. Bull. (n. s.) 37, 91 pp., illus.
(83) Swenk, M. H.
1927. The pine tipmoth in the Nebraska National Forest. Nebr. Agr. Expt. Sta. Research Bull. 40, 50 pp., illus.
(84) United States Department of Agriculture, Bureau of Entomology.
1927. The relation of insects to slash disposal. U. S. Dept. Agr. Dept. Circ. 411, 12 pp.
(85) Watson, E. B.
1931. The hemlock looper infesting balsam in the Province of Quebec. Quebec Soc. Protect. Plants (1929–30) Ann. Rept. 22: 89–91.
(86) Wildermuth, V. L., and Caffrey, D. J.
1916. The New Mexico range caterpillar and its control. U. S. Dept. Agr. Bull. 443, 12 pp., illus.

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